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Bruneau Hot-Spring Springsnail (*Pyrgulopsis bruneauensis*)

Annual Monitoring Report: 1997

by
Jeffrey T. Varicchione
Kelly W. Sant
G. Wayne Minshall

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Prepared for

U. S. Bureau of Land Management

Prepared by
Jeffrey T. Varricchione, Kelly W. Sant, and G. Wayne Minshall

Stream Ecology Center
Department of Biological Sciences
Idaho State University
Pocatello, Idaho 83209

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SUMMARY

This report presents the 1997 monitoring results from four sites near the Indian Bathtub that contain, or have contained, populations of the Bruneau Hot-spring Springsnail (*Pyrgulopsis bruneauensis*) and compares them with results from previous years. Three of these sites were monitored in 1990 and 1991 by Mladenka (1992), in 1992 by Robinson et al. (1992), in 1993 by Royer and Minshall (1993), and in 1994, 1995, and 1997 by Varricchione and Minshall (1995a, 1996, 1997). An additional seep at Site 3 (New Seep) was included in the 1994, 1995, and 1997 Springsnail monitoring efforts.

Springsnail population fluctuations at Sites 2 and 3 (Original Seep and New Seep) appear to be related to temperature variability. Temperatures at Site 2 were fairly stable. Temperatures at Site 3 (both Original Seep and New Seep) were often below 24°C and may have affected local Springsnail reproductive success. Rockface study Sites 2 and 3 (both Original Seep and New Seep) maintained Springsnail size-distributions and densities within the range of previous monitoring data. Additionally, Springsnail habitat parameters (food resources, water chemistry) appeared to remain fairly consistent with previous monitoring data. Some rockface habitat may become reduced in quality if bacterial-algal complexes expand further into rockface seep habitat.

A relict population of Springsnails was found 1.80 m from Hot Creek (Site 1). Experiments conducted in 1997 indicated that Springsnail movement rate probably was not the factor that has prevented recolonization. Hot Creek *Tilapia zilli* were shown to be capable of eating *P. bruneauensis*, although the Springsnails did not appear to be a preferred food. High water temperatures in the spring outflow where the relict population is found may be preventing migration to Hot Creek. Estimates of Springsnail populations at Site 2 and 3 (including Original Seep and New Seep) in 1997 were approximately 238,000 and 84,000, respectively.

The different temperature regimes and spatial separation of the Bruneau study sites suggest that the sites may harbor unique Springsnail populations. Controlled growth rate studies and population genetics studies are recommended to address this issue. Under present conditions, maintenance of adequate spring-flow appears to be the most important factor for assuring the success of Springsnail populations at the Bruneau study sites. Habitat improvement and a large scale fish-exclosure/Springsnail transplanting experiment at Hot Creek (Site 1) also are recommended.

INTRODUCTION

The snail *Pyrgulopsis bruneauensis* is an endemic species inhabiting a complex of related hot springs near the Bruneau River south of Mountain Home, Idaho. Hershler (1990) provided a complete taxonomic description of *P. bruneauensis*. Mladenka (1992) focused on the life history of *P. bruneauensis*, providing the groundwork on which this monitoring study is based. Mladenka (1992) found only two studies addressing the biology of *P. bruneauensis*: Taylor (1982) described the taxonomy of the snail and Fritchman (1985) studied its reproduction in the laboratory.

Mladenka (1992) found temperature to be the most important factor affecting the distribution of *P. bruneauensis*. Experiments showed the thermal tolerance range for the snails to be 11-35°C. Reproduction occurred between 20° and 35°C. Snail growth and reproduction were retarded at cool temperatures (<24°C). The study also found that under suitable conditions, recruitment and growth may occur at all times of the year, sexual maturity could occur within two months, maximum size could be reached within four months (both under suitable temperature conditions), and the sex ratio of Springsnails was 1:1. In laboratory experiments, Springsnails were found to survive on all types of substrate, although higher numbers were found on gravel and silt than on sand (Mladenka 1992). Rockface seeps had highly variable temperatures, but never exceeded thermal maximum temperatures. Hot Creek maintained temperatures that were less variable, but often above the Springsnail thermal maximum temperature (35°C) (Mladenka 1992).

A flood in the summer of 1991 contributed much silt, sand, and gravel to Hot Creek. In particular, Indian Bathtub was reduced to less than one-half its size before the flood because of sediment addition. Available habitat in the immediate vicinity of Indian Bathtub was reduced because of this and other sedimentation events (Mladenka 1992). The Springsnail's habitat has diminished considerably in recent years because of agricultural-related groundwater mining in the area (Berenbrock 1993). The Indian Bathtub population has apparently been reduced

to zero (Mladenka 1992). Springsnail populations were reduced drastically in Hot Creek (Site 1) by a major runoff event in July 1992 (Royer and Minshall 1993) and have since failed to recover. As of November 1997, there is no evidence to suggest that Springsnails have recolonized Hot Creek since July 1992. Gut analyses performed on two Hot Creek fish taxa, *Gambusia sp.* and *Tilapia sp.*, showed that their diets consisted of organic matter and insects, but not of *P. bruneauensis*. However, these analyses were performed in 1995, a year when Springsnails were apparently absent from Hot Creek (Varricchione and Minshall 1995b).

This report presents the continued biomonitoring of Mladenka's (1992) study sites through November 1997. Additionally, at the suggestion of Varricchione and Minshall (1997), more detailed descriptions of Springsnail populations and habitat at the rockface seep sites (2 and 3 (both Original Seep and New Seep)), along with results from experiments conducted in Hot Creek aimed at determining reasons for the lack of Springsnail recolonization at Site 1, are presented in this report.

METHODS

Site Description

Mladenka (1992) described in detail the three original Springsnail study sites (1, 2, and 3 Original Seep). Figure 1 shows the locations of the three study sites with respect to the Bruneau River. Figure 2a shows a map view of Site 1 at Hot Creek and an adjacent rockface seep. Figures 2b and 2c show front views of the hot-spring study areas (Sites 2 and 3 respectively). Royer and Minshall (1993) recommended that the Site 3 location be divided into two sub-sites: the Original Seep (right side) and a New Seep (left side) (Fig. 2c). These two seeps are approximately 4 m apart from each other and each "seep" has a distinct spring-flow. Their populations were monitored separately during 1994, 1995, 1996, and 1997. Site 2 is also comprised of two "seeps", but their population data have been combined since the first monitoring year. The purpose of the division of Site 3 was to allow the 1994, 1995, 1996, and 1997, Original Seep data to remain consistent with data from previous years and to allow for the inclusion of a recently discovered Springsnail population and habitat into monitoring efforts. [NOTE: The remainder of this report will refer to Site 3 (Original Seep) as Site 3-OS and Site 3 (New Seep) as Site 3-NS.]

Both spring-rockface and stream habitats were examined for *P. bruneauensis* at Site 1. Spring-rockface habitats were monitored at Sites 2, 3-OS and 3-NS. "Spring-flow-covered rockface", or "SFC rockface", was defined as madicolous habitat (rockface covered by a thin layer of running water). "Rockface wetted but lacking flow", or "rockface W/LF", was defined as moist rockface adjacent to spring-flow-covered rockface. Springsnails occur in both types of habitats.

Study quadrats (Appendix A) were established at each site for monitoring purposes. To estimate *P. bruneauensis* size-distribution and density-fluctuation inside a study quadrat, a meter stick (baseline) was positioned flush against the rockface and parallel to the direction of spring-flow. Ten transects,

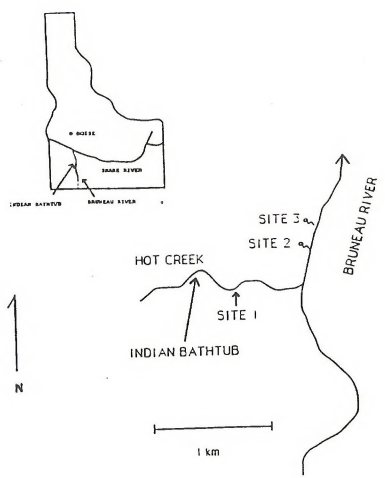

Figure 1. Map showing the locations of the Bruneau hot-spring springsnail study sites. The flow of water between Indian Bathtub and about 100 m upstream of Site 1 is primarily subsurface flow (Reprinted from Mladenka 1992).

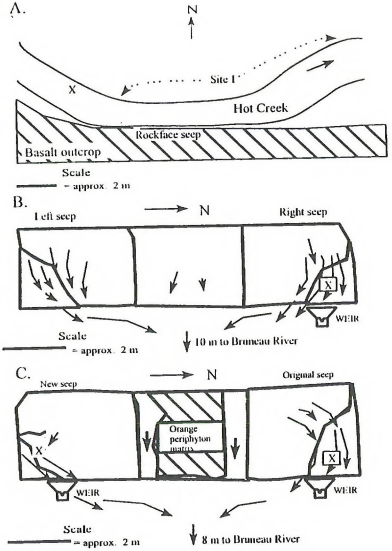

Figure 2. Temperature data logger locations for each of the study sites. Data loggers are represented by "x". A. Map view of Site 1 (Hot Creek). B. Front view of Site 2 rockface. C. Front view of Site 3 rockface (Original and New Seeps).

each perpendicular to the meter stick, were established at 10-cm intervals along the baseline. Random number lists were used to determine random rockface-sampling locations for Springsnail size and density monitoring. The random numbers were used to determine the distance across a transect each sample would be taken or monitored.

Environmental conditions were measured or monitored at the study quadrat (± 1 m) of each site on a monthly basis. These parameters included discharge and stream habitat at Hot Creek (Site 1), amount of flow-covered- and wetted-rockface (Sites 2, 3-OS, and 3-NS), water chemistry, water temperature, and food availability (periphyton abundance). Stream substrate size (particle diameter) was measured at 100 random locations along a 50-m reach of Hot Creek (Site 1 ± 25 m) beginning in June 1995 and continuing on an annual basis.

Springsnail Size Distribution

To determine if the Site 1 Springsnail population was recovering from previous flood events, arbitrary creek substrate and spring-rockface locations within a 50-m reach of Hot Creek (Site 1 ± 25 m) were examined, without magnification, for the presence of *P. bruneauensis*.

Within the sampling quadrats at Sites 2, 3-OS, 3-NS, Springsnails were washed from random locations into a standard petri dish using streams of water from a squirt bottle. The sizes of the snails were determined on site using a Bausch and Lomb dissecting microscope. The microscope ocular was marked with 0.14-mm units (under 7x magnification). Snail lengths were rounded to the nearest 0.14-mm unit (i.e. a snail whose length was 8.8 units long was noted as being in the 9-unit, or 1.26-mm, size class). Sample size was 100 for both sites 2 and 3. Beginning in 1994, population censusing at Site 3 was partitioned between the Original Seep (n=50) and the New Seep (n=50).

Springsnail Population Fluctuations

Density was not measured at Site 1 because Springsnails have

not been found there since flooding that occurred in July 1992. Springsnail density was measured at the rockface sites (Sites 2, 3-OS, and 3-NS). Densities were estimated as the number of Springsnails present within the circumference of a petri dish (8.5 cm diameter) at 10 random locations within the sampling quadrat. Densities were reported as the number of snails per m^2. A small Garrity flashlight (2 AA batteries, PR 104 bulb) was used to help distinguish the snails from the dark rockface.

Discharge, Temperature, and Water Chemistry Fluctuations

Stream water velocities were measured across a permanent transect at Site 1 (Hot Creek) using a small Ott C-2 current meter. This transect was moved slightly upstream or downstream (1 or 2 m) if instream vegetation was too thick to allow proper operation of the current meter. Stream discharge (calculated from the measured velocities) was determined using the methods described in Platts et al. (1983). Spring-flow and wetted-rockface area estimates at the rockface study quadrats adjacent to Site 1 were not possible, in general, because of the large amount of vegetation (primarily sedges) obscuring the rockface.

The amount of potential snail habitat at Sites 2 and 3 was estimated by establishing a horizontal transect across each quadrat (Appendix A). The length of the transect which passed over spring-flow-covered or wetted habitat was measured. These values were compared with the width of the transect to obtain estimates of the percentage of the quadrat area covered by spring-flow and the percentage of the quadrat rockface that was moist.

Because of the frequent breakage or loss associated with using maximum/minimum thermometers in earlier monitoring years, miniature temperature data loggers have been used at all sites beginning in 1994. Internal sensor loggers (Onset Hobo-Temp HTI-05+37) were used from 18 February 1994 to 26 September 1994, and then replaced with external sensor data loggers (Onset StowAway-Temp STEB02-05+37) on 26 September 1994 at Sites 1, 2, and 3-OS. Beginning in November 1996, an additional logger was installed at Site 3-NS. Data loggers were downloaded and relaunched

approximately every two months, in the laboratory, using LogBook for Windows v.2.03 software (Onset Instrument Corp.).

Figure 2a shows the location of the temperature data logger submersed in Hot Creek. The logger was located 2 m upstream of the regularly-examined section at Site 1. Figures 2b and 2c show the locations of the temperature data loggers at Site 2 and Site 3, respectively. Water depth at the seep study sites was quite shallow. Therefore, small pits were excavated immediately below the seep outflows in order to submerge the loggers in hot-spring water. The loggers were covered by cobble substrate or hillside talus.

Water chemistry parameters were measured for all the study sites. pH was measured, in the field, using an Orion pH meter (Model 290A). The pH meter was calibrated in the field to standard solutions (Orion pH 7.00 and pH 10.01 buffer solutions) during each monitoring visit. Conductivity (µS/cm) was measured, in the field using an Orion conductivity meter (Model 126). Water samples, for all sites, were collected in 250-ml plastic bottles, kept on ice until returned to the laboratory, and then frozen until processed. In the laboratory, samples were thawed at room temperature and shaken by hand (approximately 5 sec) to resuspend any solids. Alkalinity and hardness were determined using procedures described in Standard Methods for the Examination of Water and Wastewater (APHA, 1992).

Periphyton Levels

Periphyton samples were taken from rock substrata collected within 1 m of the study quadrats. For each sample, a modified syringe tube (3.14 cm^2) was placed on top of the substrate. Closed-cell foam, attached to the base of the modified syringe tube, formed a seal between the tube and the substrate to prevent the loss of periphyton sample. Approximately 5 ml of spring or creek water was added to the tube. A modified toothbrush was used to dislodge periphyton from the rock, and a dropper was used extract the periphyton slurry from the tube. The periphyton slurry was concentrated onto Whatman GF/F glass microfibre filters held in a Nalgene filter holder (Nalge No. 310-4000). A

Nalgene hand vacuum pump (Nalge No. 6131-0010) was used to create the suction necessary to remove the water from the slurry. For each sample, this procedure was repeated 3 times to remove all periphyton from the substrate. Periphyton samples were placed on ice, returned to the laboratory, and kept frozen until processed. In the laboratory, periphyton filters were analyzed for the presence of chlorophyll a (corrected for the presence of phaeophytin a) on a Gilford Instruments spectrophotometer (Model 2600) using procedures described in Standard Methods for the Examination of Water and Wastewater (APHA, 1992). Methanol was substituted for acetone as the solvent used in the analyses (Marker et al. 1980). Chlorophyll a, an indicator of the presence of algal organisms, was expressed as mg chlorophyll a per m^2.

The remaining periphyton material from each sample was used in the determination of algal biomass (expressed as g ash-free dry mass (AFDM) per m^2). The material was dried at 50°C for 24 h, cooled to ambient temperature in a desiccator, weighed on a Sauter balance (Model AR1014) to the nearest 10^{-4}g, combusted in a muffle furnace at 550°C for a minimum of 3 h, rehydrated, redried at 50°C, cooled to ambient temperature in a desiccator, and then reweighed. The difference in weights equaled the AFDM of the sample.

Habitat Assessment at Hot Creek

Beginning in March 1995, stream habitat assessment at Hot Creek (Site 1) was conducted monthly using the Idaho Department of Health and Welfare's Habitat Assessment Field Data Sheet for lowland streams (Appendix B; Robinson and Minshall 1995). The parameters assessed included bottom substrate/instream cover, pool substrate characterization, pool variability, canopy covering, channel alteration, deposition, channel sinuosity, lower bank channel capacity, upper bank stability, bank vegetation protection, streamside cover, and riparian vegetative zone width. Also, 100 random measurements of substrate size were made in Hot Creek on an annual basis within a 50-m reach of Hot Creek (Site 1 $\pm$ 25 m). Embeddedness of stream substrate was not measured because <30% of the substrate was composed of materials

≥ 1 cm (Varricchione and Minshall 1997). Future changes in habitat parameters should reflect recovery from prior land use activities (i.e. grazing) and recovery from earlier flooding and sediment deposition events in Hot Creek. Also, changes in these parameters, with time, should reflect any habitat improvements that may be made in the area.

ADDITIONAL METHODS FOR THE 1997 MONITORING YEAR

Springsnails still have yet to recolonize Site 1 (Hot Creek) since a major runoff event in July 1992 (Mladenka 1992, Varricchione and Minshall 1997). The following environmental and biological measurements/experiments were made/conducted in 1997 to gain greater information on the ecology of *P. bruneauensis* and to determine which factors have been preventing its recolonization of Hot Creek. Also, additional information was collected on the environmental conditions of the rockface seep sites (2, 3-OS, and 3-NS).

Environmental Measurements

Further analysis of substrate quality in Hot Creek (Site 1).

The Hot Creek streambed has become dominated by sand, silt, and small gravel as a result of grazing activity and flooding events that occurred in the early 1990's (Mladenka 1992, Varricchione and Minshall 1997). Large substrate is thought to be the best Springsnail habitat because it provides surfaces conducive to snail egg-laying (Mladenka 1992). Three trenches (0.50 m long x 0.25 m wide), spaced 50 m apart, were excavated in Hot Creek on 21 July 1997 to determine if there was a large amount of gravel and cobble substrate beneath the fine surficial sediments.

Discharge monitoring at the rockface seeps.

The water emerging from these seeps is diffuse, making it difficult to monitor flow. Small 90^0 V-notch weirs were installed approximately 1 m from the rockface seeps on 17 October 1997. The weirs collected diffuse runoff coming from the rockface to permit estimation of spring-flow discharge. The approximate location of the weirs is shown in Figure 2.

Rockface habitat mapping at Sites 2, 3-OS, and 3-NS.

Springsnail habitat area and quality were described for the

entire rockface seep areas at Sites 2, 3-OS, and 3-NS on 15 November 1997. These measurements were made in conjunction with total snail population counts (for description see below).

Biological Measurements and Experiments

Total Springsnail counts at the rockface study sites.

The current monitoring methodology does not allow for the determination of total numbers of snails present at a given site or within different habitat types on the rockface seep habitats. Therefore, an additional survey method was added to the protocol to produce estimates of total Springsnail numbers on an annual basis.

At each site, the entire rockface seep area was divided up into approximately 0.5 x 0.5 m subunits using a tape measure as a baseline across the rockface. A 8.5-cm diameter ring was placed in the center of each subunit and the snails within the ring were counted. Also, the habitat type (springflow conditions and relative cover by thick, orange periphyton complex) was estimated for each subunit.

Intensive search for relict populations of P. bruneauensis in and around Hot Creek.

Since *P. bruneauensis* has not been found at the Hot Creek study site for the past several years (Varricchione and Minshall 1997, 1996, 1995a; Royer and Minshall 1993), it is important to determine if potential recolonists for Site 1 occur anywhere in, or adjacent to, the stream between Indian Bathtub and the Bruneau River. Robinson and others (1992) had described a small stream-side refugium that had retained < 10 Springsnails after flooding and scouring events in the same year. As grazing pressure was lifted from the Hot Creek area, the growth of thick riparian vegetation near the creek and the seep made observation of this population difficult (Royer and Minshall 1993, Varricchione and Minshall 1997). An intensive search for relict populations of *P. bruneauensis* was conducted on 21 July 1997 in and immediately adjacent to Hot Creek (between Indian Bathtub and the Bruneau

River). The search was completed by examining (without magnification) Hot Creek sediments, emergent vegetation, and nearby rockface seeps for *P. bruneauensis*. Where Springsnails were found, temperatures were recorded using a Reotemp digital thermometer (model TM99A).

Controlled fish-feeding experiment in Hot Creek.

Populations of fish, redbelly tilapia (*Tilapia zilli*) and mosquito fish (*Gambusia affinis*), may be responsible for the disappearance and/or lack of recovery of the Bruneau Springsnail populations (Varricchione and Minshall 1997). These fish have been stocked worldwide, including the Great Basin ecoregion (Sigler and Sigler 1987). *T. zilli*, has a diet that is most often dominated by aquatic macrophytes, although it is believed to be omnivorous (i.e. feeding also on algae, invertebrates, and other fish). *G. affinis*, is known for its predation on mosquito larvae, but it also is known to eat a wide range of other food items (e.g. diatoms and other algae, crustaceans, and insects (Sigler and Sigler 1987)). *G. affinis* also has been documented for its cannibalistic behavior (adult consumption of juveniles) (Dionne 1985). Even if these fish do prey on *P. bruneauensis*, the operculum and shell of the Springsnails may act as a barrier to digestion in the fish gut (Norton 1988). Fish feeding on Springsnails in other locations within the Bruneau River drainage might even act as a dispersal mechanism.

Previous analysis of the gut contents of several *Tilapia* and *Gambusia* revealed no Springsnails (Varricchione and Minshall 1995b), but Springsnail populations had not been evident in Hot Creek at the time. A controlled fish-feeding experiment was conducted in 1997 to determine the extent to which the local fish might eat the Springsnails, and whether the snails can survive the process. Stomach content analysis was employed to evaluate this fish-feeding impact (Varricchione and Minshall 1995b, Dionne 1985, Gregory and Northcote 1993).

Blue plastic containers (47 cm x 34 cm), with the sides removed and replaced with 53-µm mesh to permit the flow of water, were used as experimental enclosures. The enclosures were

secured in Hot Creek (approx. 20 m upstream from the confluence of Hot Creek and the Bruneau River) with steel rods. One hundred Springsnails were collected from Site 2 and brought to the experiment location. Twenty-five Springsnails were placed in each of the 4 enclosures. In each enclosure, Springsnail composition was 5 snails which were approximately 2.10 mm and 20 snails which were approximately 0.91 mm. The first 2 enclosures contained 3 *T. zilli* each (10.33 $\pm$ 0.45 cm and 10.17 $\pm$ 0.21 in the "Springsnail-only" and "Springsnail-plus-additional-food" treatments, respectively). The second 2 enclosures contained 3 *G. affinis* each (2.78 $\pm$ 0.36 cm and 2.70 $\pm$ 0.37 cm in the "Springsnail-only" and "Springsnail-plus-additional-food" treatments, respectively). The fish had been trapped using dipnets. In one of the *T. zilli* treatments and one of the *G. affinis* treatments additional food choices were provided because these fish are believed to be omnivorous (Sigler and Sigler 1987). The additional food consisted of (approximately): 3 20-cm stream biofilm-colonized sedge stalks, 3 stream biofilm-colonized *Salix sp.* leaves, 20 g of detritus (primarily grasses), 10 adult beetles (*Cleptelmis sp.*), 2 algae-colonized rocks, and 1 10-cm macrophyte clipping (*Elodea sp.*).

The fish and potential food sources were placed into their proper enclosures at 15:30 on 14 November 1997. Upon returning at 17:30 on 15 November 1997, the enclosures were removed of their contents, which were then placed on ice. In the laboratory, the samples were kept frozen until processed. During processing, the stomachs of the fish were removed by dissection and examined under a Bausch and Lomb dissecting microscope at 7x magnification. The occurrence of organic matter and/or invertebrates (including *P. bruneauensis*) was recorded.

Movement rates of P. bruneauensis under different food resource availability conditions.

In order to determine whether the range of movement of Springsnails hindered their ability to naturally recolonize habitats from which they have been extirpated, a Springsnail movement-rate experiment was conducted in Hot Creek. To determine these rates, plastic containers (25 cm x 14 cm x 7 cm),

with the sides removed and replaced with 53-μm mesh to permit the flow of water, were used as experimental enclosures. The three enclosures contained 36 ceramic tiles (each 2.3 cm x 2.3 cm) positioned in a rectangular grid of 9 rows and 4 columns. In the first enclosure the tiles were completely devoid of algae. The second enclosure contained tiles that had been previously colonized by algae in Hot Creek for one month. These tiles were then gently scrubbed with a toothbrush to remove approximately half of the algae. Tiles in the third enclosure were colonized for one month and left undisturbed. Chlorophyll *a* and AFDM measurements were made on one tile for each of the algae treatments. Springsnails, taken from Site 2 and approximately 1.14 mm in size, were used in the experiments. Twenty-five snails were placed in each enclosure. The snails were placed on the downstream, left-most tile of the enclosures at the beginning of the experiment. Springsnail locations in the enclosures were recorded at 14:30 and 16:00 on 14 November 1997 and at 12:00 and 18:00 on 15 November 1997.

RESULTS

Springsnail Size Distribution

From 1990 to 1993, snail size distribution was monitored at three study sites: Site 1 (Hot Creek), Site 2 (upper spring rockface), and Site 3-OS (lower spring rockface) (Mladenka 1992). As suggested by Royer and Minshall (1993), a new seep at the southern edge of Site 3-NS was included in Springsnail monitoring for 1994 through 1997.

Site 1 (Hot Creek)

Site 1 (Hot Creek) population density was reduced to nearly zero in July 1992 and had yet to recover, as of November 1997 (Figs. 3h, 7). The flood in July 1992 probably resulted in the death of younger snails and skewed the size distributions in July and September 1992 (Fig. 3c). Mean size distribution data suggest that when the Springsnails were present (1990-1992), life histories were correlated with season, and a single cohort of individuals moved from juvenile classes in the winter to mature classes in the summer (Fig. 5a).

Site 2 (Upper Spring Rockface)

The Springsnail population at Site 2 maintained a size distribution that was relatively even across size classes between February and November 1997 (Fig. 3h). This trend agreed with monitoring results from previous years (Figs. 3a-g). Mean size distribution data (Fig. 5a) showed juveniles to be prevalent at all times of the year.

Site 3-OS (Lower Spring Rockface)

There were no clear size distribution trends between February and November 1997, although the warmer months (August and September) did have a larger proportion of individuals that were $\geq$ 1.5 mm, either being indicative of the growth of a cohort between the spring and summer months or outlier data (Fig. 3h).

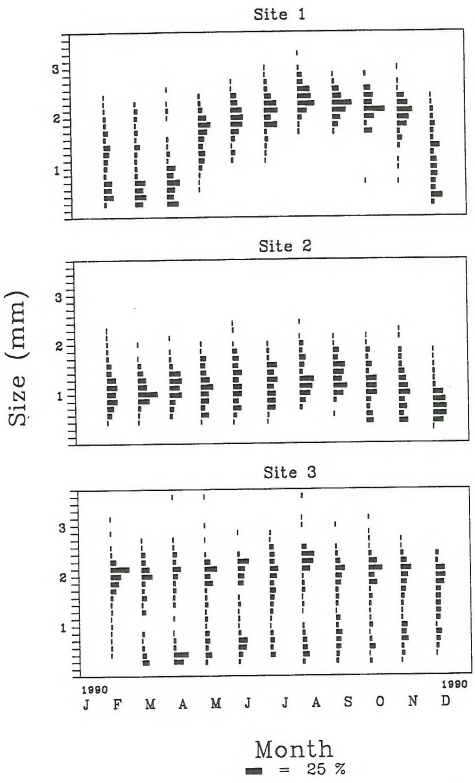

Figure 3a. Size histograms for the Bruneau Springsnail study sites. Horizontal tick marks represent 0.14mm size classes. Solid bars represent relative abundance of snails for a particular size class (n=100 for each sample).

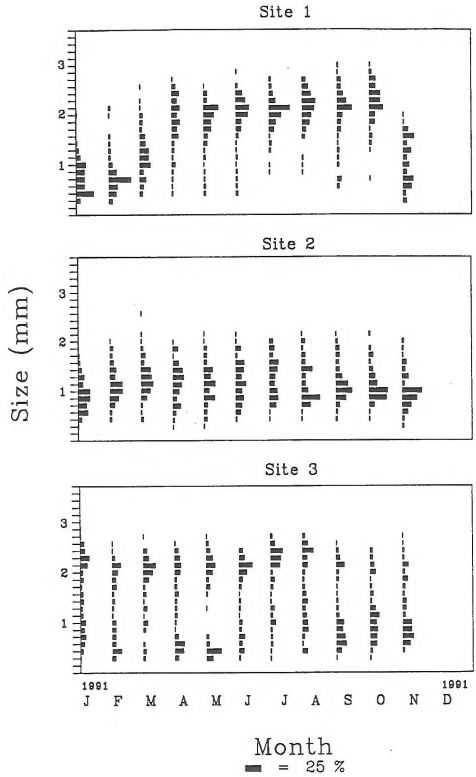

Figure 3b. Size histograms for the Bruneau Springsnail study sites. Horizontal tick marks represent 0.14mm size classes. Solid bars represent relative abundance of snails for a particular size class (n=100 for each sample).

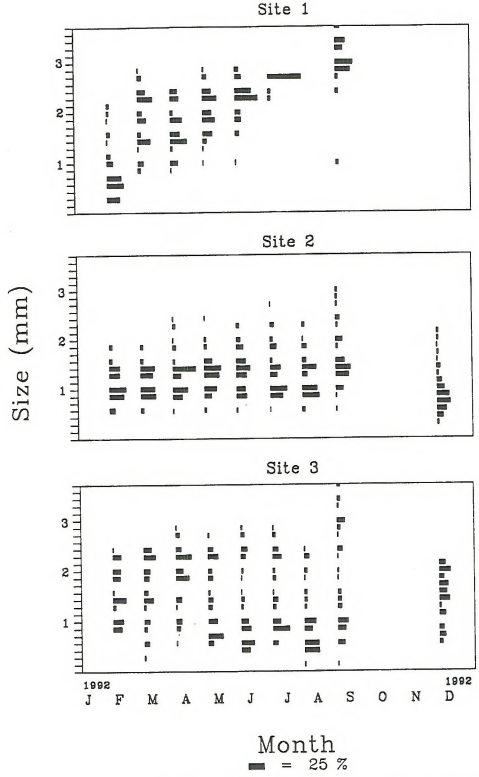

Figure 3c. Size histograms for the Bruneau Springsnail study sites. Horizontal tick marks represent 0.14mm size classes. Solid bars represent relative abundance of snails for a particular size class (n=100 for each sample). In July, 92% of the snails at Site 1 were found in the 2.66 mm size class (an out of range value for this figure).

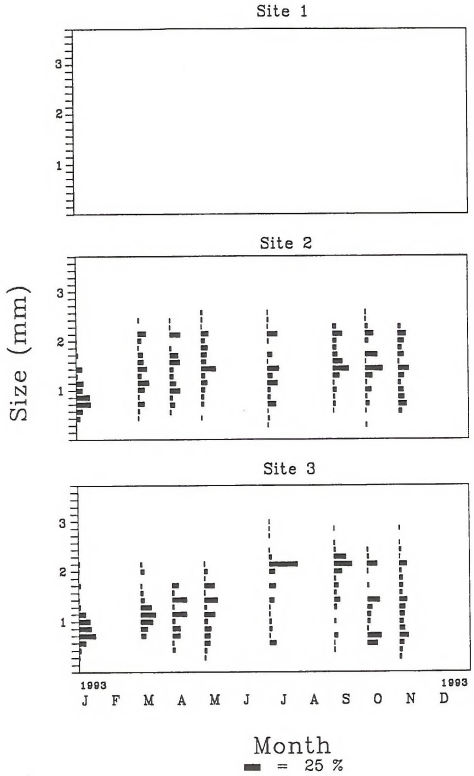

Figure 3d. Size histograms for the Bruneau Springsnail study sites. Horizontal tick marks represent 0.14mm size classes. Solid bars represent relative abundance of snails for a particular size class (n=100 for each sample).

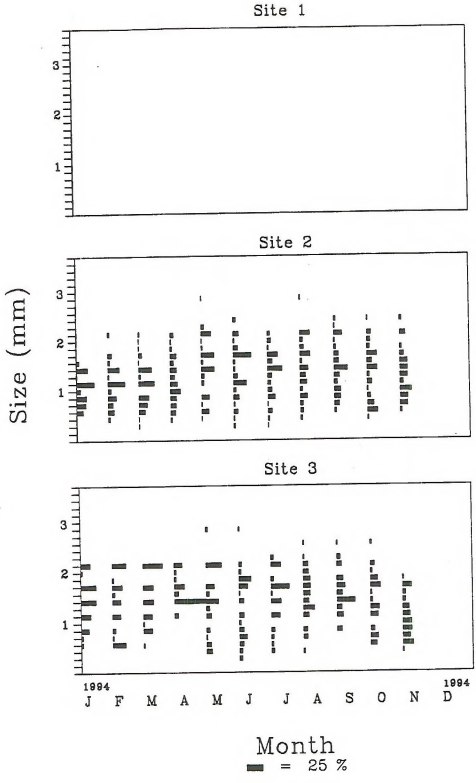

Figure 3e. Size histograms for the Bruneau Springsnail study sites. Horizontal tick marks represent 0.14mm size classes. Solid bars represent relative abundance of snails for a particular size class (n=100 for Site 2; n=50 for Site 3).

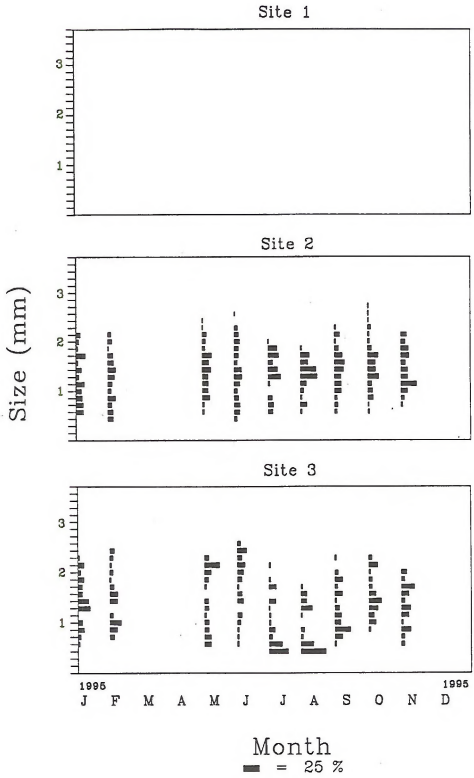

Figure 3f. Size histograms for the Bruneau Springsnail study sites. Horizontal tick marks represent 0.14mm size classes. Solid bars represent relative abundance of snails for a particular size class (n=100 for Site 2; n=50 for. Site 3).

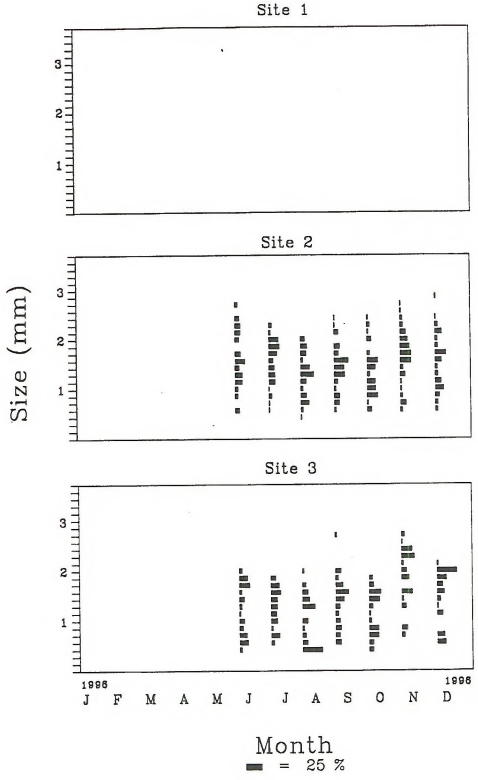

Figure 3g. Size histograms for the Bruneau Springsnail study sites. Horizontal tick marks represent 0.14mm size classes. Solid bars represent relative abundance of snails for a particular size class (n=100 for Site 2; n=50 for Site 3).

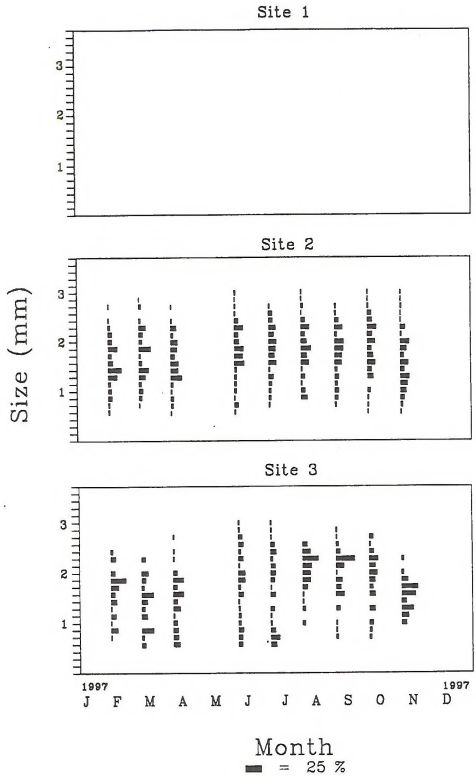

Figure 3h. Size histograms for the Bruneau Springsnail study sites. Horizontal tick marks represent 0.14mm size classes. Solid bars represent relative abundance of snails for a particular size class (n=100 for Site 2; n=50 for. Site 3).

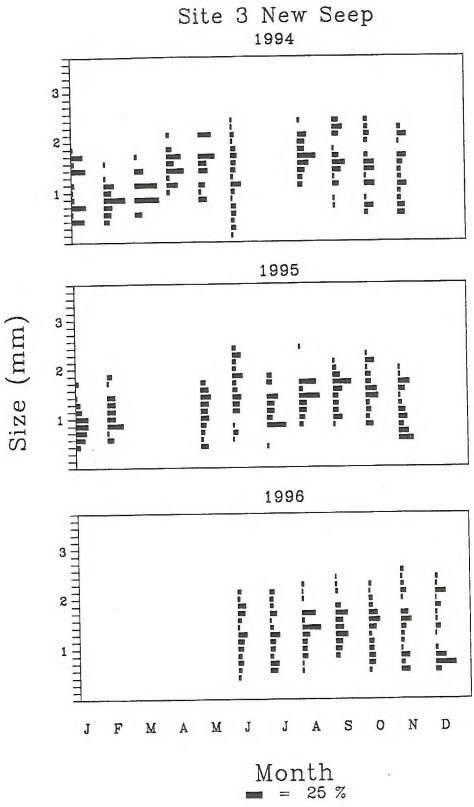

Figure 4a. Size histograms for the Bruneau Springsnail study site 3 New Seep. Horizontal tick marks represent 0.14 mm size classes. Solid bars represent relative abundance of snails for a particular size class (n=50 for each sample).

Site 3 New Seep

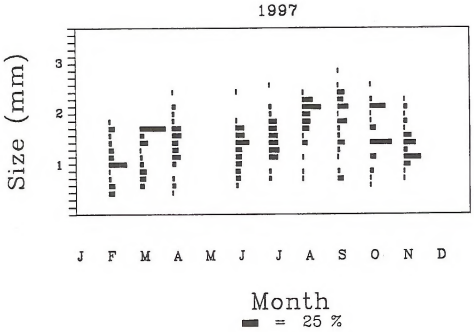

Figure 4b. Size histograms for the Bruneau Springsnail study site 3 New Seep. Horizontal tick marks represent 0.14 mm size classes. Solid bars represent relative abundance of snails for a particular size class (n=50 for each sample).

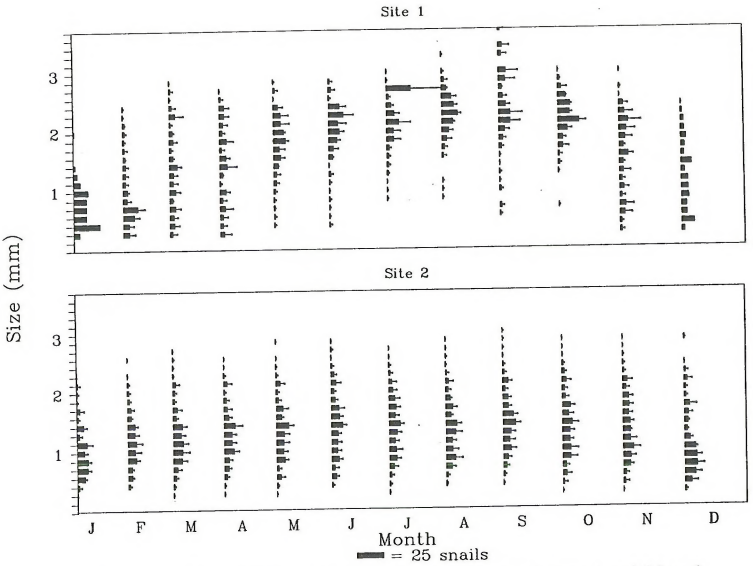

Figure 5a. Size histograms for Bruneau Springsnail study sites 1 and 2 based upon data from 1990–1997. Horizontal tick marks represent 0.14mm size classes. Error bars represent one standard deviation from the mean. Figures lacking error bars did not have enough sets of data to determine standard deviations.

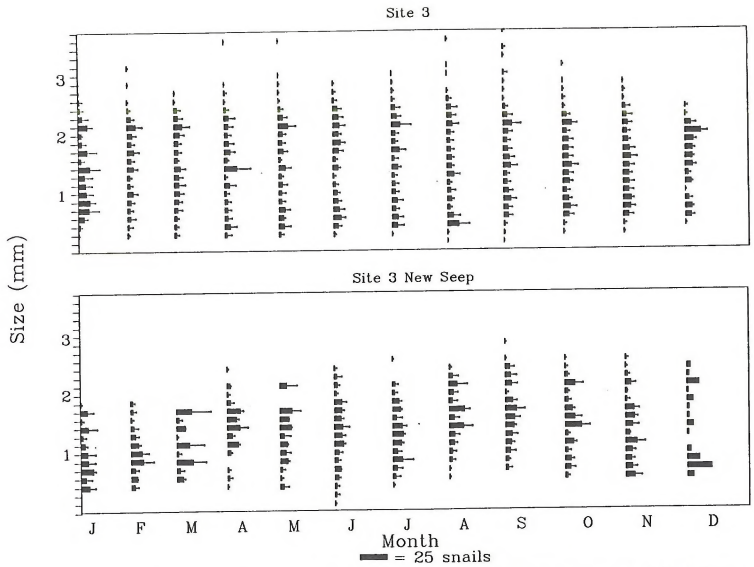

Figure 5b. Size histograms for Bruneau Springsnail study sites 3 and 3 New Seep based upon data from 1990–1997. Horizontal tick marks represent 0.14–mm size classes. Error bars represent one standard deviation from the mean. Figures lacking error bars did not have enough sets of data to determine standard deviations.

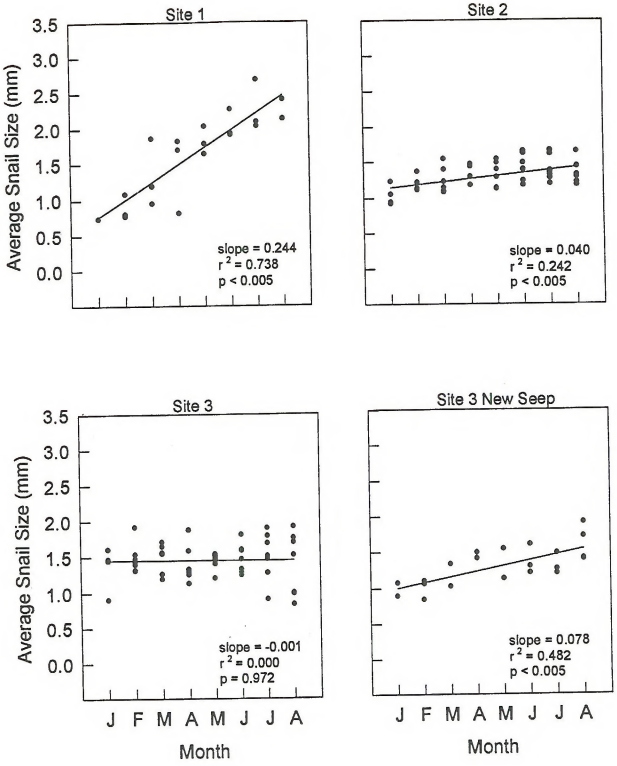

Figure 6. Estimated Springsnail growth rates based upon average monthly size (mm) at study sites 1, 2, 3-OS, and 3-NS. See text for explanation of months chosen for analyses. Years included in the analyses were 1990 - 1992 (Site 1), 1990 - 1997 (Sites 2 and 3-OS), and 1994 - 1997 (Site 3-NS).

Mean size distribution data for the Springsnail population at Site 3-OS did not show clear trends associated with season over the past eight years (Fig. 5b). Individuals appeared to be dispersed fairly evenly across the size classes each month.

Site 3-NS

Between February and November 1997, the Springsnail population at Site 3-NS also lacked any clear trends in size distribution, although the population appeared to mature in August and September (Fig. 4b). Because this agreed with the trend at Site 3-OS (Fig. 3h), it is likely that a cohort of individuals matured during this period at both Site 3 study sites (OS and NS). Mean size distribution data suggested that the New Seep population maintained a fairly even distribution of individuals across the different size classes during all seasons and that the development of cohorts at both Site 3 seeps might not be a frequent occurrence. There was a slightly higher proportion of juveniles present at the New Seep during the cold months (January-March and December) (Fig. 5b). Also, there was a noticeable lack of individuals > 2.5 mm at Site 3-NS relative to the other monitoring sites.

Comparison of Average Monthly Snail Sizes Among Sites

An analysis of the average monthly snail sizes, based upon data collected between 1990 and 1997 (Fig. 6), revealed distinct differences in population life histories among the study sites. The slopes of the linear regressions calculated in Figure 6 were used as estimates of site-specific population growth rates. Snails at Site 1 appeared to grow as a distinct cohort. The water temperatures at Site 1 were the warmest (often above the thermal maximum temperature of 35°C (Fig. 10; Mladenka 1992)). Recruitment probably only occurred in the cooler winter months, based upon the small average snail sizes found between January and March. The slope of the regression line for Site 1 (0.244; $p < 0.005$) (Fig. 6) was strongly positive and appeared to represent a gradual aging of the population between January and August. September was the month when another cohort appeared to begin its development in Hot Creek (Fig. 5a), so Figure 6 does not take the

months of September through December into account. Site 1 also had the largest average snail size of all the study sites (Fig. 6). The populations at the other sites (2, 3-OS, and 3-NS) did not exhibit as strong trends as Site 1 (analyzed between January and August for comparative purposes). Both Site 2 and Site 3-NS had significant regression lines ($p < 0.005$) with slightly positive slopes (0.040 and 0.078, respectively). Site 3-OS data was very scattered and even exhibited a slightly negative trend between January and August (slope = -0.001, $p = 0.972$).

Springsnail Population Fluctuations

Site 1 (Hot Creek)

Storm flow in Hot Creek during July 1992 resulted in major channel scouring and sediment loading. As a result, Indian Bathtub was filled with sediment. Consequently, the Hot Creek (Site 1) population of *P. bruneauensis* was reduced to nearly zero (Robinson et al. 1992). Snails have not been found in Hot Creek since 1993. It is likely that *P. bruneauensis* has been extirpated from this site (Fig. 7; Royer and Minshall 1993). A stream-side refugium that had retained snails (<10 individuals) in the past (Robinson et al. 1992) continued to do so in 1993. Royer and Minshall (1993) noted that in May 1993 this refugium became overgrown with dense terrestrial vegetation. These conditions have persisted, inhibiting observations, since that time. A more intensive search of this area on 21 July 1997 revealed, again, a small population of Springsnails at this small rockface seep (approx. 10 x 10 cm) that is 1.8 m from Site 1 (Hot Creek). This finding will be discussed in a later section of the report.

Site 2 (Upper Spring Rockface)

The highest Springsnail density at Site 2 in 1997 was 12,081 snails/m^2 in April and the lowest density was 5663 snails/m^2 in October (Fig. 7). These numbers fell within the range of data from previous years. Densities at Site 2, between 1990 and 1997, have generally been higher than those at the other study sites, although monthly estimates have exhibited great variability (Fig.

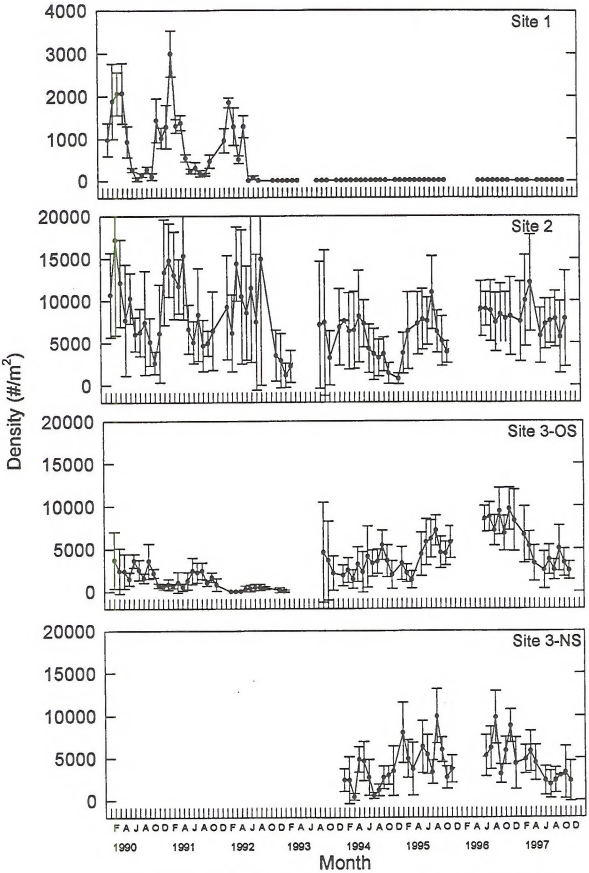

Figure 7. Mean density of the Bruneau Springsnail at the four study sites. Error bars represent one standard deviation from the mean. Note the different Y-axis for Site 1.

7). Typically, lower densities at Site 2 were found during colder months (September through February) (Fig. 7).

Site 3-OS (Lower spring rockface)

In 1997, the Site 3-OS Springsnail population maintained fairly constant densities between the months of February and November. With the exception of 1992 and 1996, densities were within the range of data from previous monitoring years (Fig. 7). The highest snail density at this site was 6628 snails/m^2 in February while the lowest density was 2416 snails/m^2 in November (Fig. 7).

Site 3-NS

Snail densities at Site 3-NS were generally lower than those at Sites 2 and 3-OS (Fig. 7). In 1997, the highest density, 5789 snails/m^2, was recorded in March and the lowest density, 1862 snails/m^2, was recorded in July. Densities in 1997 were within the range of values estimated in previous years (Fig. 7). Currently, Site 3-NS does not provide a habitat suitable for large populations of Springsnails because of its small rockface area, large amount of shading, and diffuse groundwater flow. Still, this seep does support a viable population. Improvement in habitat (e.g. augmentation of groundwater flow) probably would result in increased density and total population numbers.

Discharge, Temperature, and Water Chemistry Fluctuations

Site 1 (Hot Creek)

Hot Creek discharge dropped after channel scouring and sediment loading in July 1992 (Fig. 8). Discharge after the start of 1993 fluctuated greatly, probably as a result of precipitation (Fig. 8). Reduced discharge in Hot Creek resulted in higher maximum water temperatures for 1992 (Mladenka 1992). This relationship did not hold as strongly between 1993 and 1996 (Fig. 8). Extreme temperatures at Site 1 prior to September 1994 (date when minimum-maximum thermometers were replaced with submersible temperature data loggers) may have been the result of

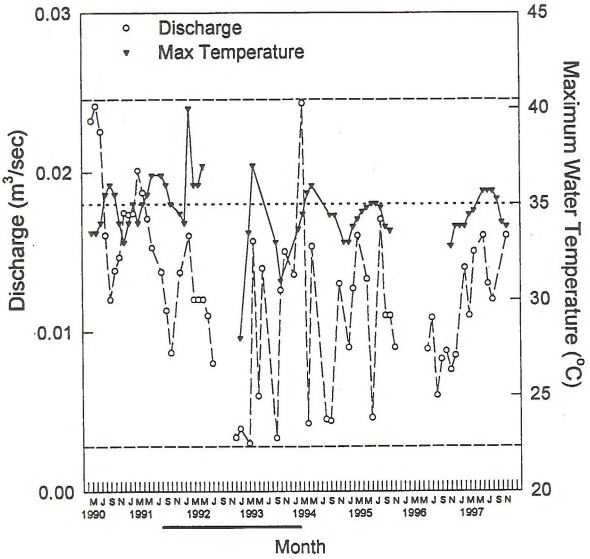

Figure 8. Discharge and maximum water temperatures for Site 1 (Hot Creek). Dashed horizontal lines indicate the maximum and minimum discharges measured at Hot Creek. Dotted horizontal line indicates thermal maximum temperature for *P. bruneauensis*. Dark bar under x-axis represents probable outlier period for temperature. See text for additional comments.

thermometer exposure to air (Fig. 8, 9; Royer and Minshall 1993, Varricchione and Minshall 1997). Water temperatures in 1997 ranged from 32 to 36°C, which is consistent with trends after September 1994 (Fig. 9). There was no apparent change in water chemistry at Site 1 during 1997 (Fig. 10), although, there was an increase in hardness during the month of June.

Site 2

At the left seep in 1997, the percent springflow-covered (SFC) rockface ranged from 10 to 30% (Fig. 11 top). The percent rockface-wetted-but-lacking flow (W/LF) in 1997 ranged from 95 to 100%, which was slightly higher than previous years (Fig. 11 bottom). At the right seep, the percent SFC rockface in 1997 fluctuated 5 and 25%, which was lower than previous years (Fig. 11 top). In 1997, percent rockface W/LF at the right seep ranged between 95 and 100%, which was generally higher than previous years (Fig. 11 bottom). Very low water temperatures at Site 2 in 1993 were probably the result of thermometer exposure to air (Royer and Minshall 1993). Site 2 maintained relatively constant temperatures during 1997 (Fig. 9). Minimum temperatures (31°C) were recorded in April and maximum temperatures (35°C) were recorded in July through October (Fig. 9). Water chemistry for 1997 was similar to values from previous years (Fig. 10).

Site 3

The percent SFC rockface for Site 3-OS in 1997 ranged from 8% in September to 30% in June, and agreed with data from previous years (Fig 11 top). The percent rockface W/LF in 1997 ranged between 95 and 100%, which also agreed with data from previous years (Fig. 11 bottom). Very low water temperatures at Site 3-OS in 1993 were probably the result of thermometer exposure to air (Royer and Minshall 1993). In 1997, temperatures varied widely, as in other years, from 19 to 31°C (Fig. 9). Water chemistry for 1997 was similar to values from other years (Fig. 10). However, there was a slight increase in hardness in September of this year.

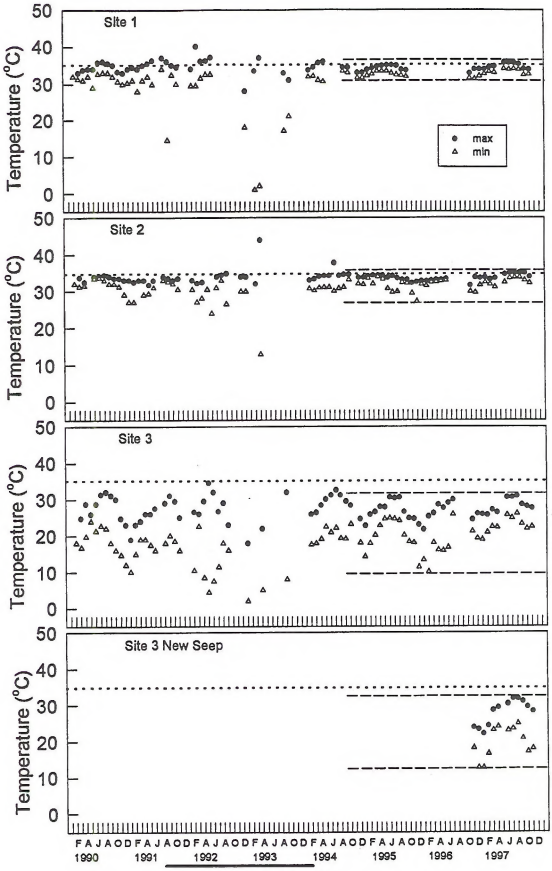
Site 1
Site 2
Site 3
Site 3 New Seep
Temperature (°C)
max
min
F A J A O D F A J A O D F A J A O D F A J A O D F A J A O D F A J A O D F A J A O D F A J A O D
1990 1991 1992 1993 1994 1995 1996 1997
Month

Figure 9. Maximum and minimum water temperatures for the Bruneau Springsnail study sites. Dashed horizontal lines indicate maximum and minimum temperatures recorded after September 1994 (external-sensor logger data). Dotted horizontal lines indicate thermal maximum temperature for *P. bruneauensis*. Dark bar under x-axis represents probable outlier period. See text for additional comments.

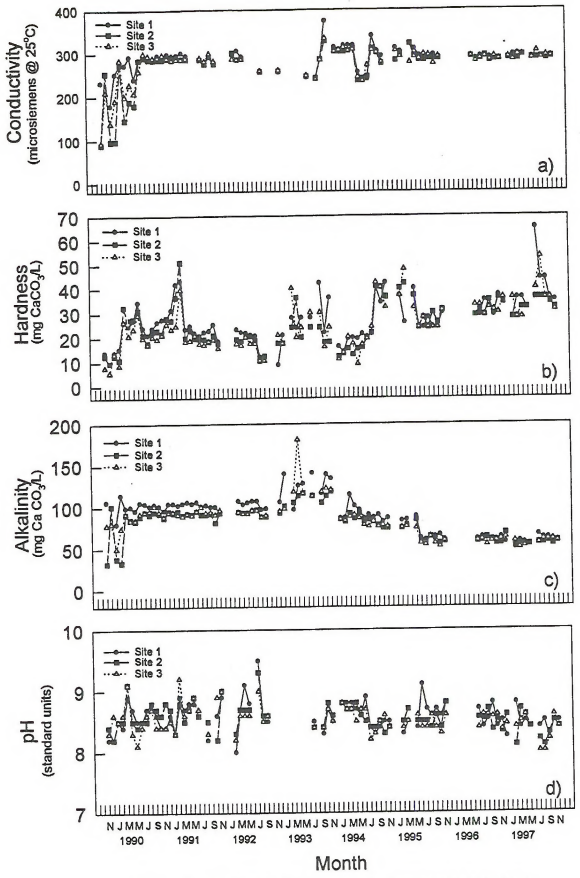

Figure 10. Conductivity (a), hardness (b), alkalinity (c), and pH (d) for the Bruneau Springsnail study sites.

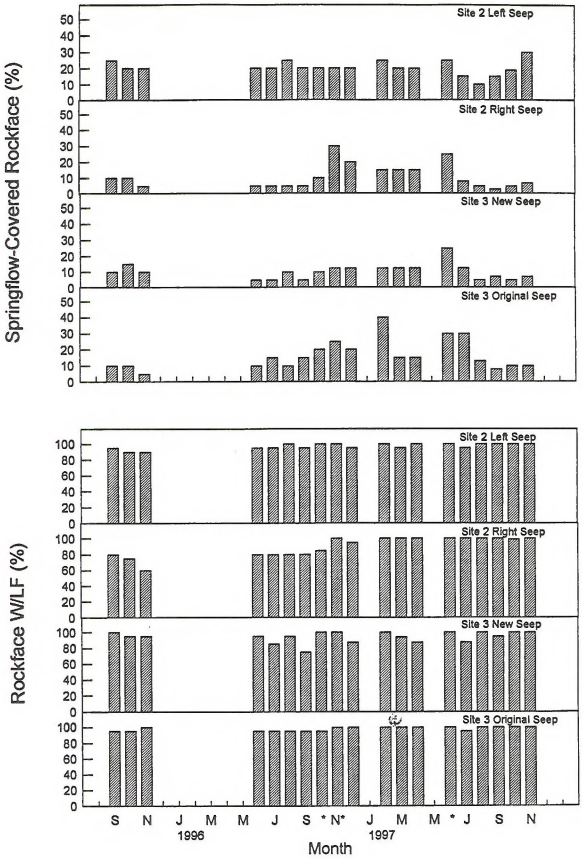
Springflow-Covered Rockface (%)
Site 2 Left Seep
Site 2 Right Seep
Site 3 New Seep
Site 3 Original Seep
Rockface W/LF (%)
Site 2 Left Seep
Site 2 Right Seep
Site 3 New Seep
Site 3 Original Seep
S N J M M J S * N* J M M * J S N
1996
1997
Month

Figure 11. (Top) Percent springflow-covered rockface (SFC rockface) and (bottom) percent rockface, wetted, but lacking flow (rockface W/LF) for the Bruneau Springsnail study sites. Asterisks indicate that sampling occurred during rain events.

Site 3-NS

In 1997, the percent SFC at Site 3-NS ranged from 5 to 25% (Fig. 11). Percent rockface W/LF ranged from 85 to 100% (Fig. 11). Water temperatures at Site 3-NS were the most variable of all the study sites, ranging from 13 to 32°C (Fig. 9). Water chemistry remained consistent with data from previous years (Fig. 10).

Periphyton Levels

Site 1 (Hot Creek)

In 1997, the highest value for chlorophyll a, 155.4 mg/m^2, was obtained in February, and the lowest value, 7.2 mg/m^2, was obtained in April (Fig. 12). The highest value for AFDM, 76.2 g/m^2, was obtained in February, and the lowest value, 5.2 g/m^2 was obtained in March (Fig. 13). These values fell within the range from previous monitoring years. Chlorophyll a and AFDM values tended to be higher at Site 1 than at any other study site (Figs. 12, 13).

Site 2 (Upper Spring Rockface)

In 1997, the highest value for chlorophyll a at Site 2, 38.1 mg/m^2, was obtained in November, and the lowest value, 3.8 mg/m^2, was obtained in February (Fig. 12). The highest value for AFDM, 18.7 g/m^2, was obtained in February, while the lowest value, 5.5 g/m^2 was obtained in September (Fig. 13). These values fell within the range of measurements from previous years.

Site 3-OS (Lower Spring Rockface)

Chlorophyll a values for Site 3-OS were highest in March (25.4 mg/m^2) and were lowest in February (1.8 mg/m^2) in 1997, and were generally lower than values from previous years (Fig. 12). The highest value for AFDM, 11.0 g/m^2, was obtained in June, and the lowest value, 3.3 g/m^2 was obtained in August (Fig. 13). These values fell within the range of measurements from previous years, but were on the lower end of the range.

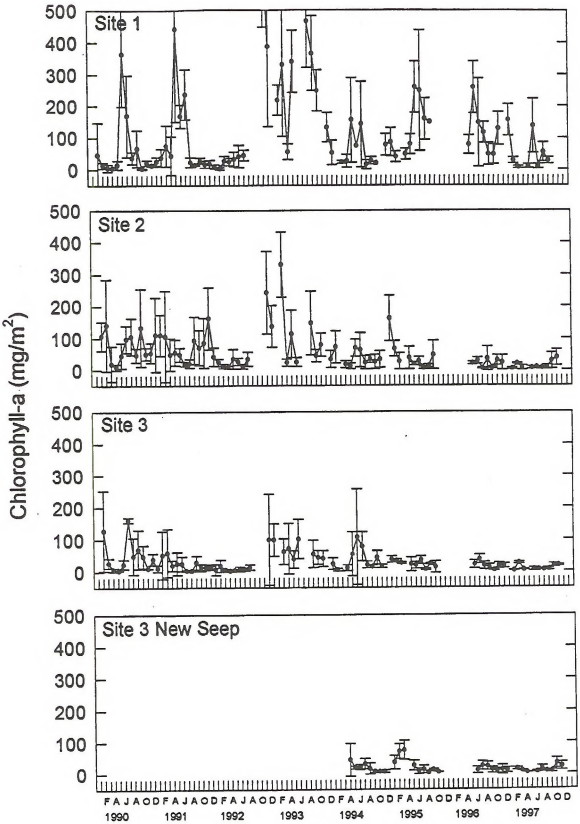

Figure 12. Periphyton chlorophyll-a values for the Bruneau Springsnail study sites. The value for Site 1 in December 1992 was 742.7 mg/m^2. Error bars represent one standard deviation from the mean. (n = 5 for Sites 1 and 2; n = 3 for Site 3 and 3 New Seep).

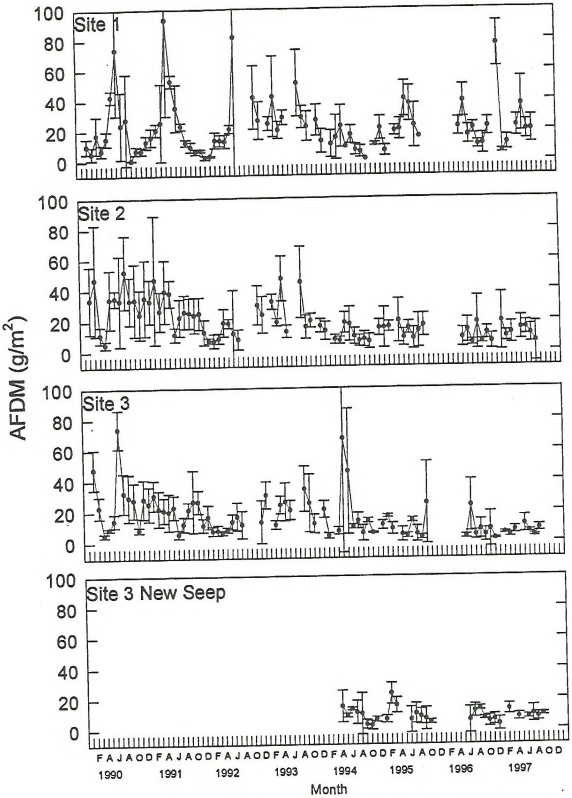

Figure 13. Periphyton ash-free dry mass (AFDM) values for the Bruneau Springsnail study sites. Error bars represent one standard deviation from the mean. (n=5 for Sites 1 and 2; n=3 for Site 3 and Site 3 New Seep).

Site 3-NS

The highest value for chlorophyll a, 31.1 mg/m^2, was obtained in October, and the lowest value, 2.4 mg/m^2, was obtained in April (Fig. 12). The highest value for AFDM, 12.7 g/m^2, was obtained in February, and the lowest value, 7.4 g/m^2 was found in August (Fig. 13). In general, these measurements were slightly lower than those from previous years.

Habitat Assessment at Hot Creek

Using the Idaho Department of Health and Welfare Habitat Assessment Field Data Sheet for lowland streams (Appendix B), habitat assessment scores were obtained on a monthly basis for Hot Creek beginning in 1995. At the recommendation of Varricchione and Minshall (1997), habitat scoring was only conducted in July in 1997. Conditions remained fairly constant between 1995 and 1997, with only seasonal changes in vegetation being apparent (Table 1). Overall, scores for the riparian community were intermediate to high, while substrate scores were low (Table 1). Particle size distribution data showed that $\geq$ 65% of Hot Creek's substrate was less than 1 cm in diameter for the years 1995 through 1997 (Fig. 14). In addition, $\geq$ 29% of Hot Creek's substrate was less than 0.1 cm in diameter (Fig. 14).

Table 1. Habitat assessment scores for Site 1 (Hot Creek).

Year	Month	Bottom Substrate	Pool Substrate	Pool Variability	Canopy Cover	Channel Alteration	Deposition	Channel Sinuosity	Channel Capacity	Bank Stability	Bank Vegetation	Streamside Cover	Riparian Width	Total Score	Percent of Maximum
Maximum score possible:		20	20	20	20	15	15	15	15	10	10	10	10	180	100
1995	March	4	5	5	16	12	2	10	9	8	8	6	5	90	50
	May	4	5	5	16	12	2	10	9	8	8	8	5	92	51
	June	4	5	5	15	12	2	10	9	9	9	5	5	90	50
	July	4	5	5	14	12	2	10	9	9	10	5	5	90	50
	August	4	5	5	14	12	2	10	9	9	10	5	5	90	50
	September	4	5	5	14	12	2	10	9	9	10	5	5	90	50
	October	4	5	5	15	12	2	10	9	9	10	5	5	91	51
	November	4	5	5	15	12	2	10	9	9	9	6	5	91	51
1996	June	4	5	5	15	12	2	10	9	8	9	5	5	89	49
	July	4	5	5	14	12	2	10	9	8	10	5	5	89	49
	August	4	5	5	14	12	2	10	9	8	10	5	5	89	49
	September	4	5	5	14	12	2	10	9	8	10	5	5	89	49
	October	4	5	5	15	12	2	10	9	8	10	5	5	90	50
	November	4	5	5	15	12	2	10	9	8	10	6	5	91	51
	December	4	5	5	16	12	2	10	9	8	9	6	5	91	51
1997	July	4	5	5	15	12	2	10	9	8	10	5	5	90	50

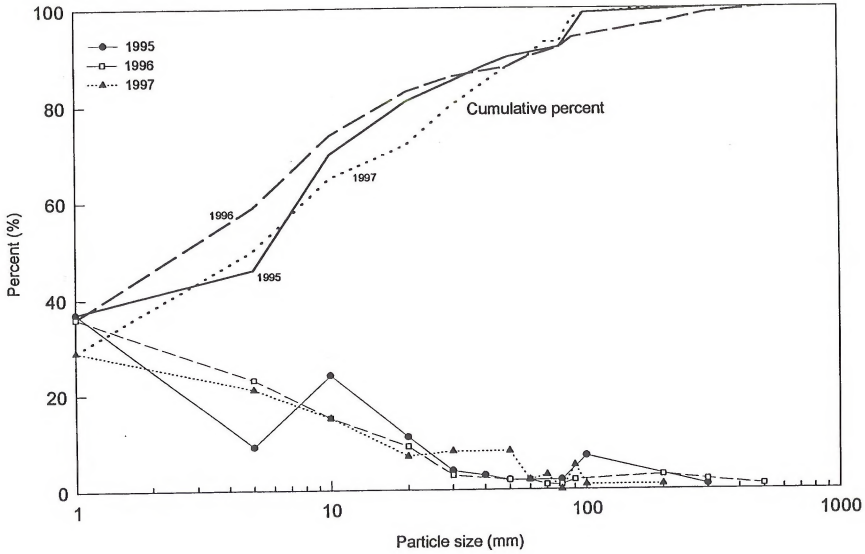

Figure 14. Substrate particle size distributions for Hot Creek (Site 1) for 1995-1997. Lines without symbols represent cumulative percent particle distribution.

RESULTS FROM THE ADDITIONAL 1997 METHODS

Environmental Measurements

Further analysis of substrate quality in Hot Creek (Site 1).

The excavated materials from the three trenches in Hot Creek were described qualitatively and analyzed for an estimated percent size-composition (Fig. 15). A cobble-dominated substrate was not found in the excavations (Fig. 15). At trenches 1 and 3 (50 m upstream and downstream from Hot Creek, respectively), 60-90% of the substrate materials (by volume) were sand and clay. The rest of the materials in these trenches had particle diameters between 2 and 5 cm. Both of these trenches were located approximately 15 m from a talus slope. Trench 2 was located within Site 1 (Mladenka 1992; Fig. 1) and was 1 m from a talus slope. This slope probably contributed large of rock to the streambed in this location (including the only piece of substrate that was > 10 cm in all of the excavations). The top 15 cm of streambed at Trench 2 was composed primarily of sand and silt (40%) and substrate in the 2 to 5 cm size class (60%). The 15-35 cm depth region was 20% silt/sand, 50% in the 2 to 5 cm size class, and 30% in the 5-10 cm size class. According to Mladenka's (1992) description of Site 1 at the beginning of his study, the streambed he described appears to be currently at least 15 cm below the streambed surface.

Discharge monitoring at the rockface seeps.

Discharge measurements at all of the weirs increased between October and November in 1997. Site 3-NS had the lowest weir readings (0.34 - 0.39 L/min), Site 3-OS had the greatest range of readings (2.17 - 5.20 L/min), and Site 2 Right Seep had the highest weir readings (5.28 - 6.10 L/min) (Fig. 16). Additional measurements are needed before making any interpretations of the data.

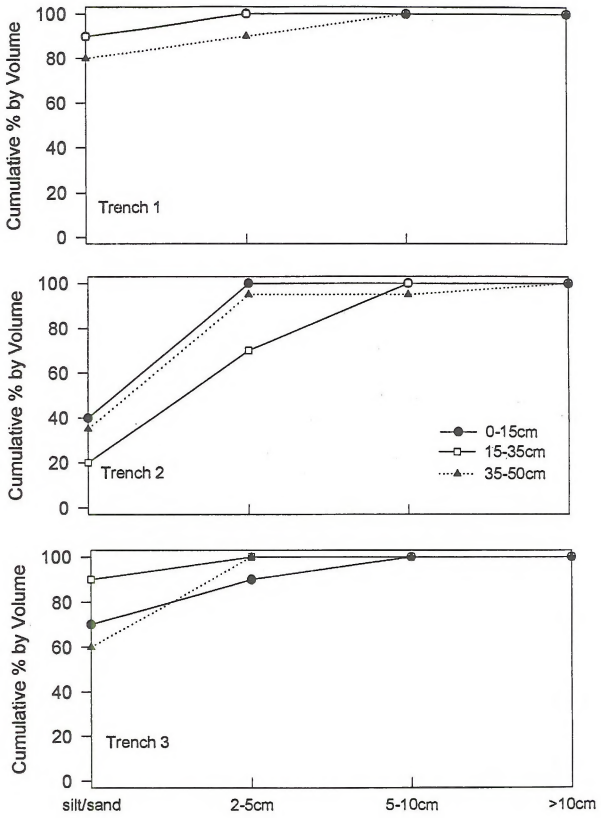

Figure 15. Estimated composition of substrate at different depths for three trenches in Hot Creek. Numbers are expressed in terms of cumulative percent by volume. Trenches 1 and 3 were located approximately 15 m from a talus slope, while trench 3 was located 1 m from a talus slope.

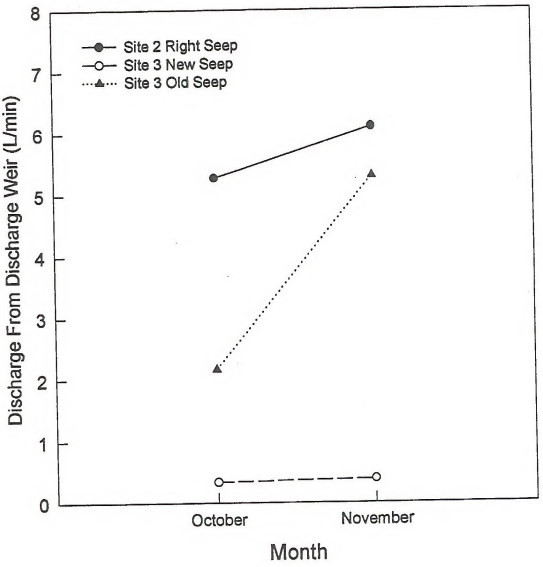

Figure 16. Discharge for the weirs placed approximately 1 m downstream from the rockface seep sites (2, 3-OS, and 3-NS). Values are expressed in L/min.

Rockface habitat mapping at Sites 2, 3-OS, and 3-NS.

Results from the rockface mapping efforts are discussed within the next section.

Biological Measurements and Experiments

Total Springsnail counts at the rockface study sites.

Measurements estimated Springsnail numbers to be greater than 238,000 within the 18.25 m^2 of rockface sampled at Site 2 (Fig. 17) and greater than 84,000 within the 18.25 m^2 of rockface sampled at Site 3 (Fig. 18; including both 3-OS and 3-NS). Their distribution was quite patchy and was probably a result of the heterogenous habitat conditions on the rockfaces (Figs. 2, 17, 18). Analyses of variance on log(x+1)-transformed density data indicated that significantly different number's of Springsnails were found among moist and flowing-water rockface habitats (Fig. 19a) and among varying levels of thick periphyton growth on the rockfaces (Tukey's test; Fig. 19b). Springsnail densities were higher in a flowing-water regime than in a moist-only (extremely low flow) habitat condition (Fig. 19a; $p < 0.01$). Springsnail densities decreased with an increase in the presence of thick, orange periphyton complex (composed of diatoms and, most likely, various forms of hot-spring-adapted bacteria) on the rockface (Fig. 19b).

Intensive search for relict populations of P. bruneauensis in and around Hot Creek.

An intensive search along the length of Hot Creek revealed that there was still an apparent absence of Springsnails in Hot Creek. A small rockface seep, approximately 1.80 m out from Hot Creek and approximately 2.00 m in the downstream direction from Site 1 on Hot Creek, is in the same location as that described by Robinson et al. (1992). For the months of August, September, and November 1997, the mean number of Springsnails at the seepage/rockface portion of this outflow was 36.7 $\pm$ 20.8 (per 10 cm^2) (Fig. 20a). These numbers declined with distance from the rockface (described by the equation $y = 35.92e^{(-0.102x)}$; $r^2 = 0.72$)

0,D,0	0,D,0	0,D,0	0,D,0	0,D,0	? F,0	? M,75	0,D,0	? M,50	? F,50	? M,75	0,D,0
0,D,0	0,D,0	0,D,0	0,D,0	0,D,0	? F,0	? M,75	? M,75	1.85 M,75	1.85 F,25	0.92 M,75	0,D,0
0,D,0	0,D,0	0,D,0	0,D,0	0,D,0	7.38 F,0	3.69 M,75	4.61 M,50	12.92 M,25	2.77 M,25	0.92 M,75	0,D,0
0,D,0	0,D,0	0,D,0	0,D,0	0,D,0	9.23 F,0	0.92 M,75	5.54 M,75	18.46 M, 25	10.15 M,50	0,D,0	0,D,0
0,D,0	0,D,0	0,D,0	0,D,0	0,D,0	6.46 F,0	9.23 F,0	3.69 M,75	18.46 M,25	12.00 M,25	0,D,0	0,D,0
1.29 M,50	1.11 F,0	0,D,0	0,D,0	11.07 M,25	12.92 F,0	14.77 F,0	2.77 M,100	2.77 F,0	0.92 M,50	5.54 M,75	9.23 M,75
0.92 M,75	10.15 F,0	5.54 M,100, OH	0,D,0	9.23 M,50	5.54 F,0, OH	1.85 M,0					
0.92 V,0	11.07 M,0										

BASELINE

50

^ 6.0 m

scale : ———— = 0.50 m

0 m ^

Left Seep

Right Seep

^ nail @ 6.2 m (1.2 m below baseline)

Figure 17. Springsnail density estimates and rockface habitat descriptions for Site 2. Springsnail estimates are shown first, followed by rockface moisture ("D" = dry, "M" = moist, and "F" = flowing water), and then percent thick algal-cover. Springsnail densities are expressed as (number x 1000)/m2. "OH" indicates that the rockface is shaped as an overhang and "V" indicates that the area is dominated by vegetation overlying a layer of soil on top of the rockface. Shading indicates zero Springsnails present, dry rockface, and an absence of living algae. On 15 November 1997, the estimate of total number of Springsnails was 238,660 within a rockface area of 18.25 m^2 (subunits marked with "?" were excluded from estimates).

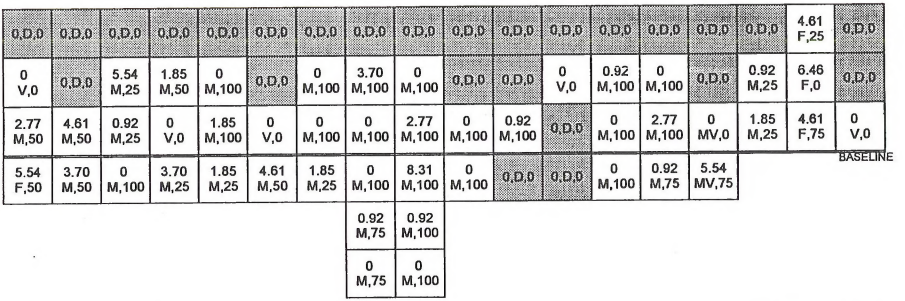

Figure 18. Springsnail density estimates and rockface habitat descriptions for Site 3 (including Original and New Seep). Springsnail estimates are shown first, followed by rockface moisture ("D" = dry, "M" = moist, and "F" = flowing water), and then percent thick algal-cover. Springsnail densities are expressed as (number x 1000)/m2. "OH" indicates that the rockface is shaped as an overhang and "V" indicates that the area is dominated by vegetation overlying a layer of soil on top of the rockface. Shading indicates zero Springsnails present, dry rockface, and an absence of living algae. On 15 November 1997, the estimate of total number of Springsnails was 84,930 within a rockface area of 18.25 m^2.

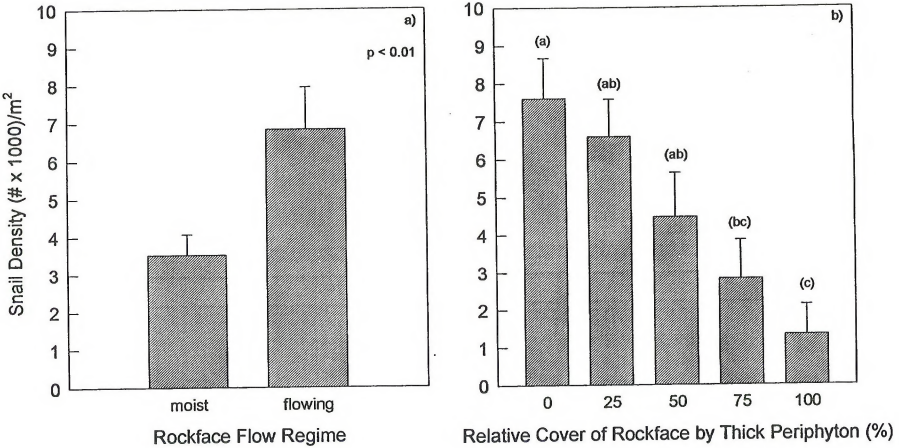

Figure 19. Distribution of Springsnails at rockface seep study sites (2, 3-OS, 3-NS) in relation to a) rockface flow regime and b) percent rockface covered by thick, orange periphyton. Flow regime and periphyton cover estimates were made qualitatively and are presented in Figs. 17 and 18. Rockface units (Figs. 17, 18) that either were dry or dominated by vascular plant vegetation were not used in these analyses. Statistical analyses were performed on log (x+1) transformed Springsnail densities. Different lower-case letters over bars in b) denote significantly different means ($p < 0.05$), as determined by Tukey's test.

to zero at 1.20 m from the rockface (approx. 0.60 m from the outflow's junction with Hot Creek)(Fig. 20a). On 14 November 1997, temperature measurements were made simultaneously with snail counts. Conducted twice to ensure precision, the temperature began at 34.6°C at the rockface, declined to 33.1°C at 0.10 m from the rockface in the outflow/stream, increased again to 34.5°C at 0.40 m, and declined again to 33.4°C at 0.80 m (Fig. 20b). Temperatures over the rest of the tributary were relatively constant (33.8°C $\pm$ 0.10). The range in these temperature readings was only 1.5°C and may reflect precision limits of the thermometer.

Controlled fish-feeding experiment in Hot Creek.

Tilapia in the "Springsnail plus additional food sources" treatment did not prey on live Springsnails, although one fish did contain a bleached shell of an unidentified gastropod (Fig. 21) The bulk of the remaining stomach contents for this treatment was dead organic matter (detritus) and living vegetative matter (fragments of macrophytes). One *Tilapia* in the "Springsnails only" treatment had a small (1.1 mm) *P. bruneauensis* in its stomach (Fig. 21). The composition of the remaining stomach contents in this treatment was very similar to the other *Tilapia* treatment. *Gambusia* in the "Springsnail plus additional food sources" treatment did not prey on live Springsnails (Fig. 21). Most of the remaining stomach contents for this treatment was detritus. One elmid beetle (*Cleptelmis sp.*) larvae was found in a *Gambusia* from this treatment. The composition of the remaining stomach contents in the "Springsnail plus additional food" treatment was primarily detritus, but also included vegetative matter and one elmid beetle (*Cleptelmis sp.*) larvae (Fig. 21).

Movement rates of P. bruneauensis under different food resource availability conditions.

Low chlorophyll a abundance on the tiles in the experimental enclosures appeared to induce a considerable amount of dispersal of Springsnails in the "zero-algae" (0 mg chlorophyll a/m^2) treatment relative to the "half-algae" (35.1 mg chl a/m^2)

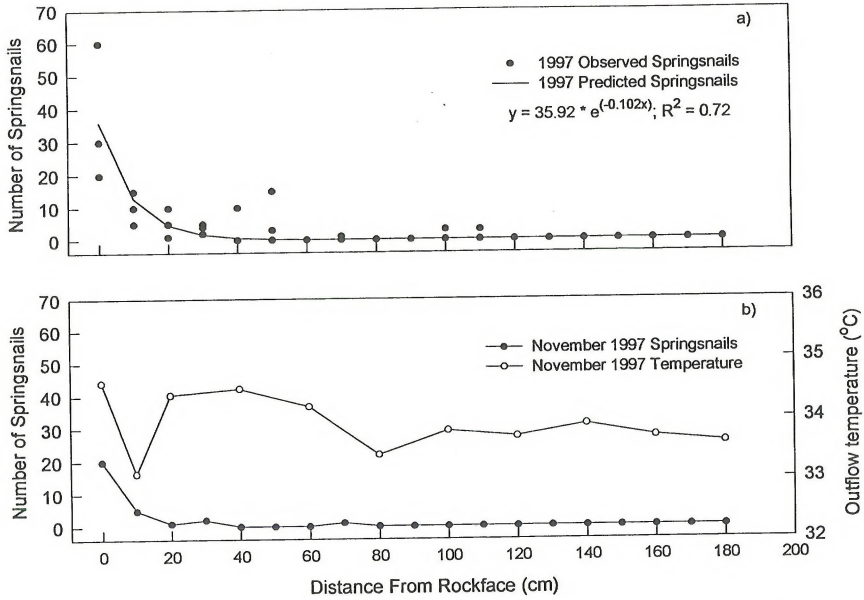

Figure 20. Relict Springsnail distribution data for rockface seep outflow near Site 1 at Hot Creek. (A) Observed and predicted distribution of Springsnails from combined August, September, and November 1997 data. (B) Distribution of Springsnails and water temperature at same location on 15 November 1997. Observations at 0 m were taken directly from the rockface while the remaining observations were made in the deeper (approx. 10 cm) outflow. The area for each observation was approximately 10 cm^2.

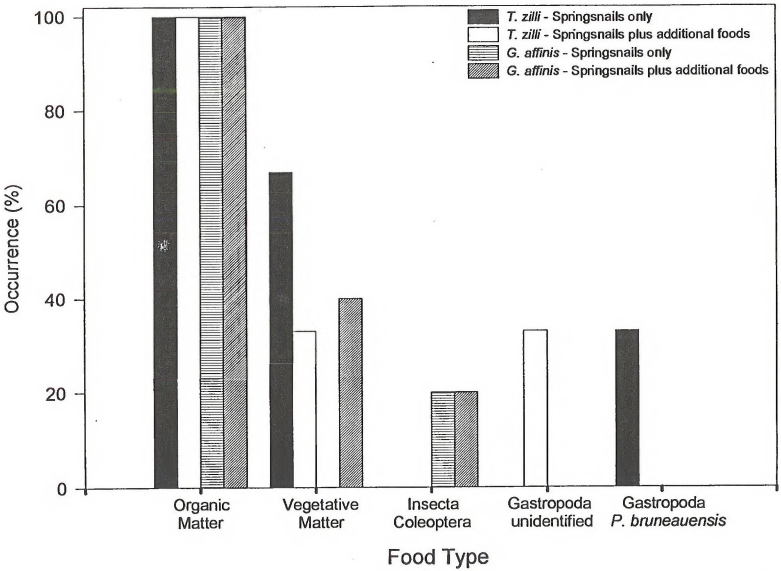

Figure 21. Occurrence of food types in the guts of *Tilapia zilli* (n = 3 for each treatment) and *Gambusia affinis* (n = 5 for each treatment) under Sprinsnail-only and Springsnail-plus-additional-food availability treatments in the controlled fish-feeding experiment in Hot Creek, Bruneau, Idaho.

treatment and "full-algae" (63.7 mg chl a/m^2) treatment within the first 1.5 hours after the experiment had begun (Fig. 22a). Springsnails in both algae-colonized tile treatments appeared to be more prone to stay in their initial location because of greater food availability. After 21.5 hours (Fig. 22b) and 27.5 hours (Fig. 22c), the amount of Springsnail dispersal within the experimental enclosures appeared to increase greatly in the "half-algae" and "full-algae" treatments. In all cases, the median distances traveled by Springsnails were similar ($\pm$ 4 cm) within each sampling period (Fig. 22). Also, in all cases, some Springsnails had traveled 21.8 cm (the greatest distance possible in the enclosures) by the 21.5 hour sampling.

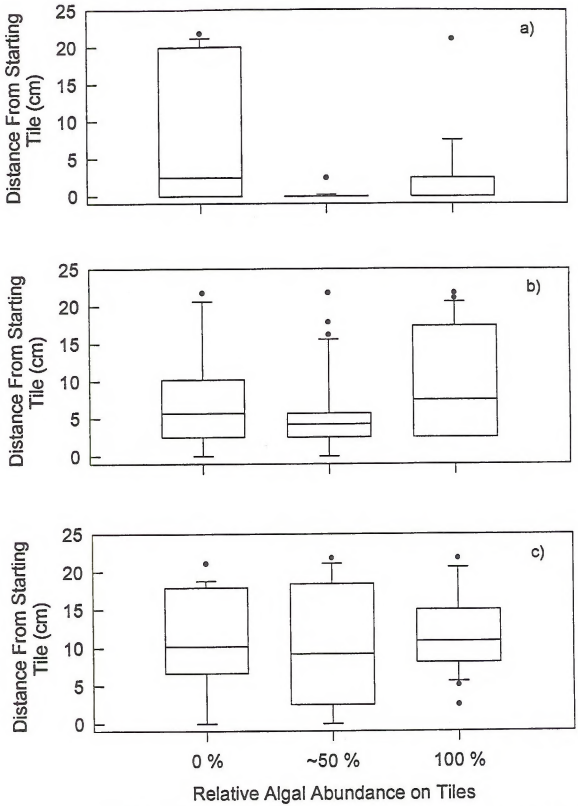

Figure 22. Box plots of Springsnail distance from the starting tiles in each of the three algae-colonized tile treatments at Hot Creek in Bruneau, Idaho. The experiment began at 14:30 on 14 November 1997. Springsnail locations on tiles were noted at 16:00 on 14 November 1997, b) 12:00, and c) 18:00 on 15 November 1997. Horizontal lines represent the 25%ile, median, and 75%ile. The "error bars" are the 10%ile and 90%ile. Solid circles are outliers.

DISCUSSION

Conditions at Indian Bathtub and Hot Creek

The only place that Springsnails were found in or near Hot Creek was on a rockface 1.80 m from the creek. The population at the rockface was small (36.7 $\pm$ 20.8 cm per 10 cm^2) and declined exponentially to zero 0.60 m before the outflow joined with Hot Creek. A number of factors may be responsible for the lack of Springsnail recolonization. These factors may include poor substrate quality, predation (most likely by fish), an inability to move long distances, and unsuitable temperature regimes. Experiments and field measurements were done in 1997 to assess the relative importance of these factors.

The Indian Bathtub and Hot Creek areas have been greatly impacted by sedimentation in recent years. A flood in the summer of 1991 contributed much silt, sand, and gravel to Hot Creek. In particular, Indian Bathtub was reduced to less than one-half its size before the flood because of sediment addition. Available habitat in the immediate vicinity of Indian Bathtub was reduced because of this and other sedimentation events (Mladenka 1992). Additionally, the Springsnail's habitat has diminished considerably in recent years because of agricultural-related groundwater mining in the area (Berenbrock 1993). The Indian Bathtub population has apparently been reduced to zero (Mladenka 1992). Springsnail populations were reduced drastically in Hot Creek (Site 1) by a major runoff event in July 1992 (Royer and Minshall 1993) and have since failed to recover. As of November 1997, there is no evidence to suggest that Springsnails have recolonized Hot Creek since July 1992.

Hot Creek does not have a cobble-dominated substrate layer near the surface of the streambed. Most of the materials are sands and small gravels. Although Mladenka's (1992) study showed that Springsnails are able to survive on all sizes of substrate, large substrate is important because it provides a stable surface for egg-laying. The area near Mladenka's (1992) study area does have a substrate layer composed primarily of gravels, but that

layer is at least 15 cm below the streambed surface.

It appears that Springsnails (at least those 0.91 through 2.10 mm in size) are not a preferred food item for the exotic fish in Hot Creek. However, the controlled fish-feeding experiment, conducted in November 1997, did show evidence of Hot Creek fish occasionally consuming gastropods (one *T. zilli* consumed a *P. bruneauensis* and another consumed a bleached and unidentified snail shell). Snails were not found in the gut contents of Hot Creek fish in 1995 (Varricchione and Minshall 1995b), but that finding may have been a result of the (apparent) lack of Springsnails in Hot Creek. Any Springsnails that do migrate to Hot Creek may be immediately preyed upon by fish, preventing any chance of re-establishing a stable population. However, the results of our feeding experiments suggest that the snails are mainly eaten incidental to the ingestion of other foods. Possible preference of the fish for very small Springsnails, veligers, or eggs remains unknown and may warrant additional study.

At the spring seep near Hot Creek (Site 1), temperatures in the outflow may limit Springsnail populations. The temperature in the outflow was at the high end of the temperature tolerance range found by Mladenka (1992). This logic is supported by the fact that the highest densities of the relict population were found on the rockface where exposure to air could cool the snails if they were too hot. However, it seems unlikely that the temperatures downstream of the outflow acted as a barrier to Springsnail movement, even though no snails were found further than 1.1 m from the spring (Fig. 20).

Movement rate studies indicated that *P. bruneauensis* is capable of moving as much as 1 cm per hour. In both food-limited and -unlimited treatments, at least 2 or 3 Springsnails had moved the greatest distance within the experimental enclosures (21.8 cm) by 21.5 hours. The distance from the relict population rockface to Hot Creek (1.80 m) could theoretically be traveled in less that 9 days (and probably a much shorter time) barring any unsuitable conditions. As with temperature, movement rates do not appear to explain the lack of Hot Creek recolonization.

Other habitat parameters measured at Hot Creek (Site 1) (stream temperature, discharge, periphyton chlorophyll-a and biomass, substrate composition, and riparian habitat quality) in 1997 remained fairly consistent with data collected in previous years (at least after sedimentation events in 1991 and 1992). The lack of grazing in the area has led to a rapid recovery in riparian vegetation over the past few years.

Conditions at the Rockface Seeps

Springsnail size-distribution and density measurements, along with rockface habitat parameters (periphyton chlorophyll-a and biomass, water temperature, and chemistry, and rockface flow and moisture conditions) remained relatively consistent with data from previous years. The rockface seeps had water temperatures that were consistently lower than those in Hot Creek (Site 1) and rarely exceeded the thermal tolerance temperature (35°C) (Mladenka 1992). This most likely explains the higher amounts of year-round recruitment at the rockface seep sites (2, 3-OS, and 3-NS) compared with Hot Creek. Temperature ranges clearly affect the *P. bruneauensis* populations. Average size and growth rates were smaller, but densities were greater, at the rockface seeps than in Hot Creek (1990-1992). The rockface sites are probably more suitable for Springsnail success than Hot Creek.

Small, 90° V-notch weirs were installed at the rockface seep sites (2, 3-OS, and 3-NS) to provide a means of monitoring discharge. Although measurements have only been made for 2 months, it appears that there may be large amounts of variability in the flows. Continued monitoring should provide useful insight into the status of the local groundwater situation.

The rockface habitat mapping and total Springsnail population estimates provide a broader understanding of the status of the endangered snail and its environment at the study sites. The areas which have been monitored since 1990 have been approximately 2 m^2 at each of the rockface seep sites. The rockface mapping in 1997 relied on less intensive sampling, but it expanded population estimates and habitat descriptions up to

18.25 m^2 at both Site 2 and Site 3 (including OS and NS). These measurements should provide a base from which longterm trends in population and habitat conditions can be determined.

In 1994 Springsnail size distributions, densities, and eventually temperatures (beginning November 1996) at Site 3-NS began to be monitored. This data was kept separate from Site 3-OS, at the suggestion of Royer and Minshall (1993), so that it could be determined if its snail population was under different constraints and behaving differently than Site 3-OS. Size distribution data, life history patterns, densities, and habitat are noticeably different between the two sites. More years of monitoring are required to gather enough data to conduct appropriate statistical tests to decide if the Original Seep and New Seep data should be combined.

Some parts of the rockface study sites (Sites 2, 3-OS, and 3-NS) are covered by thick layers of periphyton. At Site 2 and Site 3-NS this periphyton is primarily composed of diatoms, green algae, and, most likely, warm-water-adapted bacteria. At Site 3-OS, blue-green algae are also an important component of this periphyton. The middle rockface area at Site 3 (Fig. 2c) is almost completely covered with a very thick layer of this periphyton matrix so it is not monitored for Springsnails. At the study sites, snail densities have not been monitored where this periphyton is thicker than a 1-2 mm. Random samples within this thick periphyton complex at each of the sites indicate that snail densities are often less than a third of what they are in clear rockface areas. These thick layers of periphyton appear to be spreading into damp areas where water is not flowing down the rockface (areas of low disturbance). As groundwater flows decrease, less rockface area will be covered by fast flowing water, and more habitat probably will be covered by this bacterial-algal complex. Given enough reduction in springflow, Springsnail populations could be reduced to abundances that are too small to remain viable.

RECOMMENDATIONS

To properly manage *P. bruneauensis* populations in the Bruneau River drainage, the biology of these Springsnails must be well understood. Mladenka (1992), Taylor (1982), and Fritchman (1985) made significant contributions to knowledge of the biology of *P. bruneauensis*. Additionally, recent population and habitat monitoring done by Idaho State University (Varricchione and Minshall 1997, 1996, 1995a, 1995b; Royer and Minshall 1993; Robinson et al. 1992) have made contributions. Still, many questions remain unanswered. The most pressing question regards the uniqueness of the Springsnail populations at the different thermal streams and springflows along the Bruneau River. Because of the different temperature regimes and the spatial separation of the populations, there is a good chance for the existence of unique gene pools and, thus, different species or subspecies of the Bruneau Hot-spring Springsnail at the various locations within the drainage. Experiments such as controlled growth-rate studies and population genetics studies may provide additional insight into the biology of the Springsnails. This insight might improve habitat management strategies for *P. bruneauensis*.

Hot Creek conditions are very poor and appear to be the result of poor land management practices on the watershed upstream of Site 1. As recommended previously by Varricchione and Minshall (1995a, 1996, 1997), Springsnail population and habitat data collected to date indicate that immediate measures should be taken to rehabilitate the Indian Bathtub-Hot Creek area and restore the habitat conditions to at least those found prior to July 1992. This is the minimum effort required to restore the Bruneau Hot-spring Springsnail to Hot Creek. Habitat restoration would show whether the Springsnail will repopulate naturally or if transplantation is necessary. Extensive dredging in Hot Creek probably would be needed before any significant improvements would be seen. Other procedures that could lead to substrate improvement might be 1) the destruction of the small dams (believed to have been installed by local residents for fish habitat) both upstream and downstream of Site 1, and 2) the placement of cobble-sized substrate on top of the current

substrate to increase the surface area of hard substrate for Springsnails to place their eggs.

Long-term restoration is dependent on sound land management practices (e.g. continued prevention of grazing on high risk areas within the watershed) and increased thermal flows. Also, a recolonization experiment would be an important step in developing a recovery plan for *P. bruneauensis* in Hot Creek. A large-scale exclosure could be built in the creek to prevent fish predation. Springsnail-covered cobbles from a rockface site could be transplanted to within the exclosures. Emergent vegetation should be included within the exclosure so that Springsnails could crawl out of the water to cool themselves. However, efforts toward transplantation should proceed cautiously until it can be determined whether populations from potential sources, including the relict population adjacent to Hot Creek, are genetically similar. In addition to these experiments, Hot Creek, Indian Bathtub, and rockface seep discharge could potentially be increased with a reduction in the intensity of groundwater mining on the surrounding agricultural lands. This habitat improvement could result in the restoration of reliable flows in perpetuity and provide a greater chance for natural recolonization.

ACKNOWLEDGMENTS

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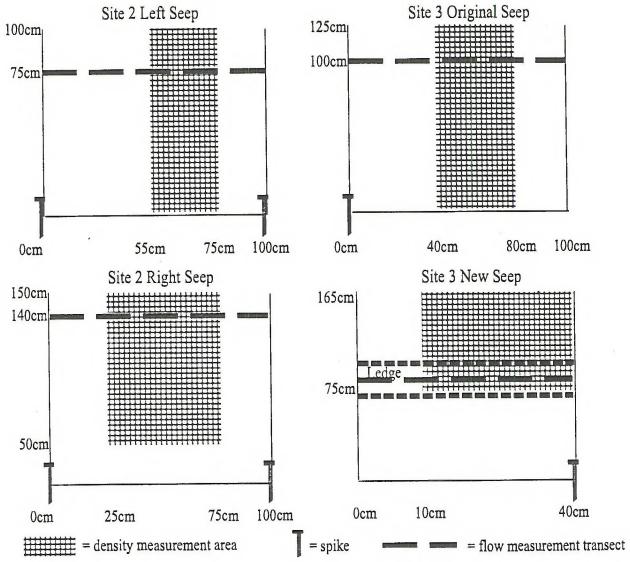

Appendix A. Springsnail density, wetted rockface, and springflow measurement locations at the rockface seeps. Maps are not drawn to scale.

Habitat Assessment, Glide/Pool Prevalence (modified after Platkin et al., 1989).

Stream Name: _____ Station: _____ Date: _____ Location Description: _____

Idaho Department of Health and Welfare - Division of Environmental Quality
HABITAT ASSESSMENT FIELD DATA SHEET
GLIDE/POOL PREVALENCE

HABITAT PARAMETER	CATEGORY: OPTIMAL	SUB OPTIMAL	MARGINAL	POOR
1. Bottom substrate/ instream cover	Greater than 50% mix of rubble, gravel, submerged logs, undercut banks, or other stable habitat. 16-20 ___	30-50% mix of rubble, gravel, or other stable habitat. Adequate habitat. 11-15 ___	10-30% mix of rubble, gravel, or other stable habitat. Habitat availability less than desirable. 6-10 ___	Less than 10% rubble, gravel or other stable habitat. Lack of habitat is obvious. 0-5 ___
2. Pool substrate characterization	Mixture of substrate materials with gravel and firm sand prevalent, root mats and submerged vegetation common. 16-20 ___	Mixture of soft sand, mud, or clay; mud may be dominant; some root mats and submerged vegetation present. 11-15 ___	All mud or clay or channelized with sand bottom; little or no root mat; no submerged vegetation. 6-10 ___	Hard-pan clay or bedrock; no root mat or vegetation. 0-5 ___
3. Pool variability	Even mix of deep/shallow/ large/small pools present. 16-20 ___	Majority of pools large and deep; very few shallow. 11-15 ___	Shallow pools much more prevalent than deep pools. 6-10 ___	Majority of pools small and shallow or pools absent. 0-5 ___
4. Canopy cover (shading)	A mixture of conditions where some areas of water surface fully exposed to sunlight, and other receiving various degrees of filtered light. 16-20 ___	Covered by sparse canopy; entire water surface receiving filtered light. 11-15 ___	Completely covered by dense canopy; water surface completely shaded. OR nearly full sunlight reaching water surface. Shading limited to < 3 hours per day. 6-10 ___	Lack of canopy, full sunlight reaching water surface. 0-5 ___

Stream Name: _____ Station: _____ Date: _____ Location Description: _____

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HABITAT PARAMETER	CATEGORY: OPTIMAL	SUB-OPTIMAL	MARGINAL	POOR
5. Channel alteration	Little or no enlargement of islands or point pars, and/or no channelization. 12-15 ___	Some new increase in bar formation, mostly from coarse gravel; and/or some channelization present. 8-11 ___	Moderate deposition of new gravel, coarse sand on old and new bars; and/or embankments on both banks. 4-7 ___	Heavy deposits of fine material, increased bar development; and/or extensive channelization 0-3 ___
6. Deposition	Less than 5 % of bottom affected; minor accumulation of coarse sand and pebbles as snags and submerged vegetation. 12-15 ___	5-30% affected; moderate accumulation of sand at snags and submerged vegetation. 8-11 ___	30-50% affected; major deposition of sand at snags and submerged vegetation; pools shallow, heavily silted. 4-7 ___	Channelized; mud, silt and/or sand in braided or multraided channels; pools almost absent due to deposition. 0-3 ___
7. Channel sinuosity	Instream channel length 3 to 4 times straight line distance. 12-15 ___	Instream channel length 2 to 3 times straight line distance. 8-11 ___	Instream channel length 1 to 2 times straight line distance. 4-7 ___	Channel straight; channelized waterway. 0-3 ___
8. Lower bank channel capacity	Overbank (lower) flows rare. Lower bank W/D ratio < 7. (Channel width divided by depth or height of lower bank.) 12-15 ___	Overbank (lower) flows occasional. W/D ratio: 8-15 8-11 ___	Overbank (lower) flows occasional. W/D ratio: 15-25 4-7 ___	Peak flows not contained or contained through channelization. W/D ratio > 25 0-3 ___

Stream Name: _____ Station: _____ Date: _____ Location Description: _____

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HABITAT PARAMETER	CATEGORY: OPTIMAL	SUB-OPTIMAL	MARGINAL	POOR
9. Upper bank stability	Upper bank stable. No evidence of erosion or bank failures. Side slopes generally < 30°. Little potential for future problems. 9-10 ___	Moderately stable. Infrequent, small areas of erosion mostly healed over. Side slopes up to 40° on one bank. Slight potential in extreme floods. 6-8 ___	Moderately stable. Moderate frequency and size of erosional areas. Side slopes up to 60° on some banks. High erosion potential during extreme high flow. 3-5 ___	Unstable. Many eroded areas. "Raw" areas frequent along straight sections and bends. Side slopes 60° common. 0-2 ___
10. Bank vegetative protection OR Grazing or other disruptive pressure	Over 90% of the streambank surfaces covered by vegetation. 9-10 ___ Vegetative disruption minimal or not efficient. Almost all potential plant biomass at present stage of development remains. 9-10 ___	70-89% of the streambank surfaces covered by vegetation. 6-8 ___ Disruption evident but not affecting community vigor. Vegetative use is moderate, and at least one-half of the potential plant biomass remains. 6-8 ___	50-79% of the streambank surfaces covered by vegetation. 3-5 ___ Disruption obvious; some patches of bare soil or closely cropped vegetation present. Less than one half of the potential plant biomass remains. 3-5 ___	Less than 50% of the streambank surfaces covered by vegetation. 0-2 ___ Disruption of streambank vegetation is very high. Vegetation has been removed to 2 inches or less in average stubble height. 0-2 ___

Stream Name: _____ Station: _____ Date: _____ Location Description: _____

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	CATEGORY			
HABITAT PARAMETER	OPTIMAL	SUB-OPTIMAL	MARGINAL	POOR
11. Streamside cover	Dominant vegetation is shrub. 9-10 ___	Dominant vegetation is of tree form. 6-8 ___	Dominant vegetation is grass or forbes. 3-5 ___	Over 50% of the stream bank has no vegetation and dominant material is soil, rock, bridge materials, culverts, or mine tailings. 0-2 ___
12. Riparian vegetative zone width (least buffered side)	> 18 meters 9-10 ___	Between 12 and 18 meters. 6-8 ___	Between 6 and 12 meters. 3-5 ___	< 6 meters. 0-2 ___
Column Totals	___	___	___	___
Score				

Appendix C. Stage height and discharge at the rockface seep discharge weirs.

Date	Site 2 Right Seep Stage Height (cm)	Site 2 Right Seep Discharge (L/min)	Site 3 New Seep Stage Height (cm)	Site 3 New Seep Discharge (L/min)	Site 3 Original Seep Stage Height (cm)	Site 3 Original Seep Discharge (L/min)
17 Oct 97	9.8	5.28	7.3	0.34	9.7	2.17
14 Nov 97	10.1	6.1	7.5	0.39	10.5	5.3

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